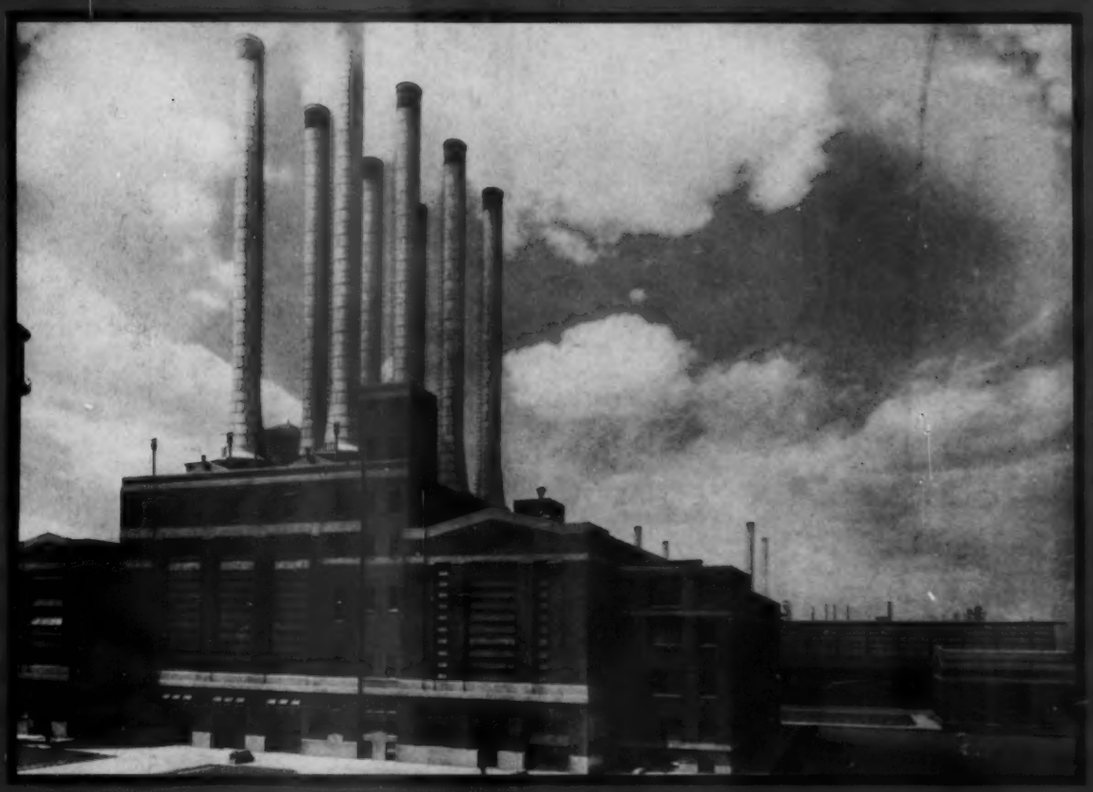
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

L. 7, No. 8 FEBRUARY, 1936 25c a copy



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Action of Solutions of Sodium Silicate and Sodium Hydroxide at 250 C on Steel under Stress

Possibilities of Boilers with Forced Circulation

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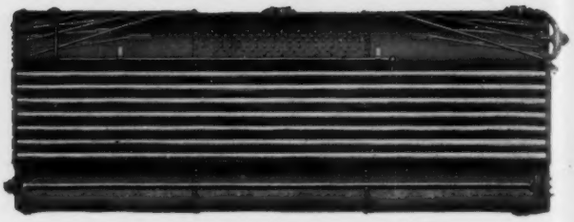
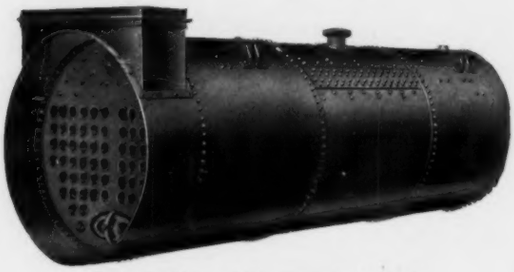


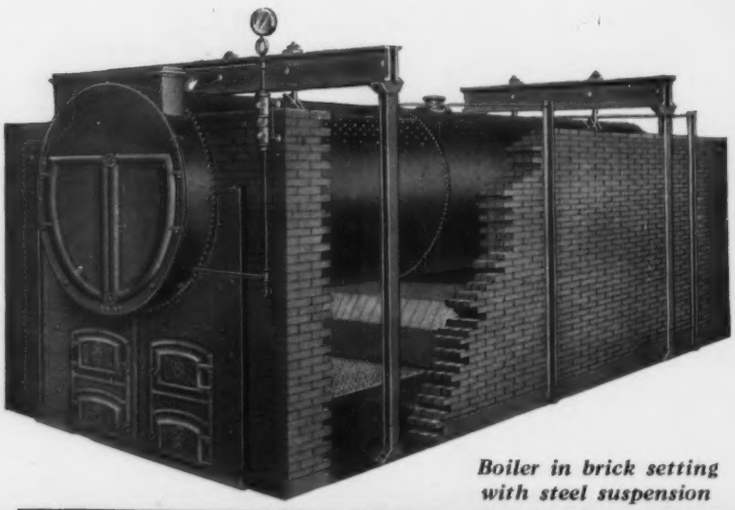
Section through boiler showing bracing

Bare boiler with welded shell

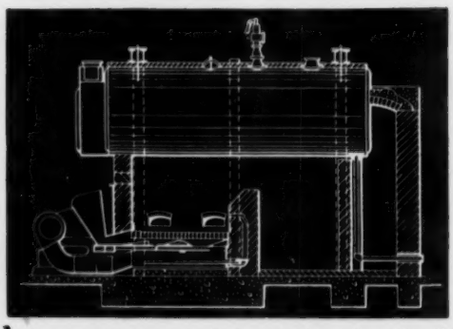


Bare boiler with extended shell

Flush end bare boiler



Boiler in brick setting with steel suspension



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COMBUSTION

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VOLUME SEVEN NUMBER EIGHT

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CCA

CORROSION..

WHAT IS CORROSION

An abnormal waste of metals by impurities in the water. According to the derivation of the word corrode, *Cor* means together; *Rode*, gnaw; or gnawing together. This early understanding is significant, because corrosion according to every practical conclusion today in the field is more or less influenced or accelerated by more than one constituent in the water.

MANIFESTS ITSELF HOW

Either in the form of pit or pock-like depressions and/or grooves in the metal or through a uniform wasting away of the metal, or both.

THE DEPRESSIONS AND GROOVES ARE CAUSED BY WHAT

(a) *Principally by oxygen* and recognized as such by barnacle-like mounds of iron oxide raised over pit holes in the metal, all varying in width and depth from pin points to better than 1/4 inch.

(b) *Some by magnesium chloride* recognized by coverings of scale of less prominence than those of oxygen, but with much longer and more irregular holes beneath. The compositions of the deposits these contain are also products of corrosion.

(c) *Least by an electric cell action* in which the e.m.f. intensities of the involved metals differ and boiler concentrates function as the electrolytes. Metal losses from this type when active are invariably void of their iron oxide coverings, thus differing from oxygen and magnesium chloride.

(d) *Occasionally through stray currents* and then only with d.c. This occurs regardless of the treatments in use for preventing corrosion. Losses of this kind are also characterized by this same freedom from deposits.

(e) The grooves in metals are invariably the result of extensive close-set areas of oxygen and/or magnesium chloride corrosion.

WHAT CAUSES UNIFORM SURFACE LOSSES IN METALS

(a) *Organic and mineral acids* in waters which are invariably generally active throughout a system;

(b) *Erosion.* Losses from this cause are usually limited to areas affected by high water velocities, especially in pipes or channels where these waters are turbulent.

HOW DOES THE pH OF A WATER INFLUENCE THIS

When in excess of 8.5 it definitely retards oxygen corrosion and practically prevents magnesium chloride and any free acid action on metals. On the other hand, a lower pH value accelerates the destructive effects of oxygen and is not a definite protection against magnesium chloride and acid attacks.

Corrosion resulting through stray currents or any local electric cell action occurs in any pH range.

TREATMENTS FOR PREVENTING:

Oxygen Corrosion

Chemically, by absorbing oxygen with sodium and ammonium sulphites and phosphites, changing to sulphates and phosphates in the reactions; through the use of tannic acid in combination with caustic soda, thus producing sodium pyrogallate, an oxygen-consuming agent. In low pressure heating systems, only through the use of chromates is this possible.

Mechanically, with deaerators and/or deactivators; through coatings of Apexior or similar protective materials, and through deposits of calcium and magnesium carbonate and magnesium hydroxide.

Acid Corrosion (mineral and organic, including CO_2)

Chemically, only through the use of alkaline salts, principally caustics, in quantities sufficient for complete neutralization, can acid corrosion be prevented.

Electrolytic Corrosion

Through individual cell action by equalizing the e.m.f. differences through proper metal substitutions or total elimination if cell action results through inclusions of mill scale or other foreign material in the affected metal or metals.

Stray Currents

By locating the source and providing for diversion of the currents to a definite ground or through proper insulation at the source, or use of a rectifier for counteracting current flow.

WAYS FOR PREDETERMINING THE CAUSES OF CORROSION AND FOR REGULATING THESE UNDER OPERATING CONDITIONS:

Oxygen: Through the Winkler method;
Acids: Through pH tests and analysis for acids;
Stray Currents: Through tests with a millivolt and/or milliammeter using this same means for locating the source and strength of the current leakage.
Electric Cell Actions: None, only at time of inspection.

JUST WHAT ARE THE REACTIONS WHICH TAKE PLACE IN THE VARIOUS CORROSIVE ACTIVITIES?

Oxygen Corrosion

Iron + water = Iron hydroxide + hydrogen
Hydrogen + oxygen = Water
Iron hydroxide = Iron oxide + water

Carbonic Acid Corrosion

Iron + carbonic acid = Iron carbonate + hydrogen
Iron carbonate + oxygen + hydrogen = Iron oxide + carbonic acid

Magnesium Chloride Corrosion (Cyclic)

Magnesium chloride + water = Magnesium hydroxide + hydrochloric acid
Iron + hydrochloric acid = Iron chloride + Hydrogen
Iron chloride + Magnesium hydroxide = Iron hydroxide + Magnesium chloride

Sulphuric Acid Corrosion

Sulphuric acid + iron = Iron sulphate + hydrogen

CORROSION THROUGH STRAY CURRENTS

Stray currents + iron + water = Iron oxide + hydrogen

CORROSION THROUGH CELL ACTION

Caused by two metals in close position with widely different solution tendencies in which electric currents are generated by one of the metals going in solution.

ACCURACY OF PLANT TESTS FOR CONTROL PURPOSES

The extreme care necessary in collecting representative samples and in testing these without causing air contaminations makes the accuracy in most oxygen determinations unreliable, especially in many plants where the facilities for this kind of work are not available. This is confirmed by the fact that waters have proven corrosive in cases where oxygen, according to the Winkler method, indicated Zero and the pH decidedly alkaline under the best kind of sampling and testing.

The influence of varying loads in heater operations for removing oxygen and the incessant testing for oxygen that is necessary under such conditions does not improve this situation. The Rice organization recognized these weaknesses nearly fifteen years ago and established the practice of locating steel rods in the stream of feedwater after the heater. At that time the rods were specially treated to make them corrosion-sensitive. Since then the steel is selected and further treatments applied to increase their sensitivity to all such actions.

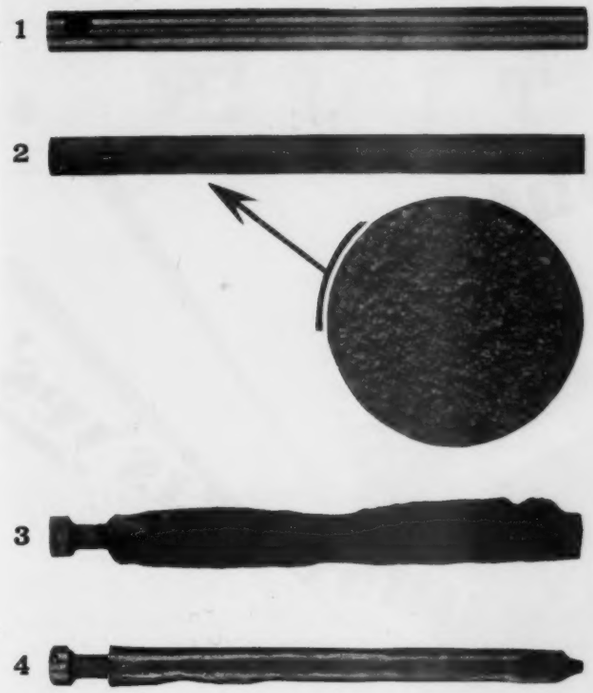

Fig. 1—Detector rod before sensitising
Fig. 2—Detector rod after sensitising. Sensitized area magnified 200 diameters
Fig. 3—Sensitized rod after 60 days exposure and before cleaning
Fig. 4—Sensitized detector rod after 60 days exposure and special cleaning

Five years later an equipment was developed for locating these rods within the streams of feedwater and for replacing them at any time under operating conditions with full pressure on the lines.

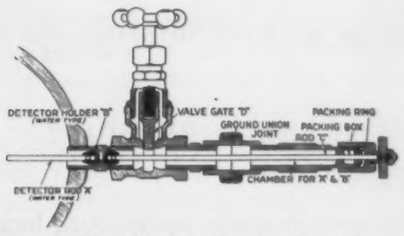

Fig. 5—Rice detector. For locating and replacing detector rods under full line pressure

THE VALUE OF SUCH A PRACTICE IS APPARENT BECAUSE

(a) The constant location of the rods in the main stream of feedwater is more representative in its determinations than snap water sampling such as characterizes most analytical methods;

(b) Their removal and inspection at will avoids the delay of waiting for a shut-down to determine the corrosive effects of the water in use;

(c) The rods do not limit their detection of such properties to a specific water constituent, but expose the effects of all of them in a form that leaves no doubt as to the accumulative corrosive activities of the water;

(d) They are definitely positive in such conclusions;

(e) The retention of these rods for future comparisons also brings into use a record that is definitely dependable in proving the value of any prior treatments for correcting the corrosive properties of a water;

(f) This use of the sensitized rods also eliminates from the daily schedule, many tests for oxygen, CO_2, etc.;

(g) It supplies a means for checking the dependability of such tests.

While sensitized rods register the corrosive properties of a water, the extent and kind of the alkaline concentration, together with which the velocity of the circulating waters prevent the corrosive gases from attaching themselves to the under-water metal surfaces, has a very direct bearing on the final result. This knowledge led to the development of the detector plate and special plate holder about ten years ago.

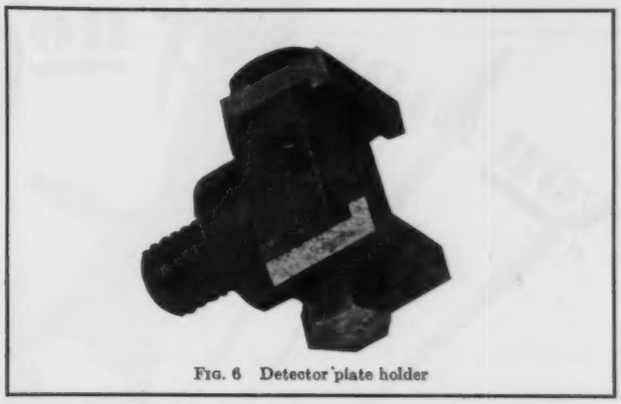

Fig. 6 Detector plate holder

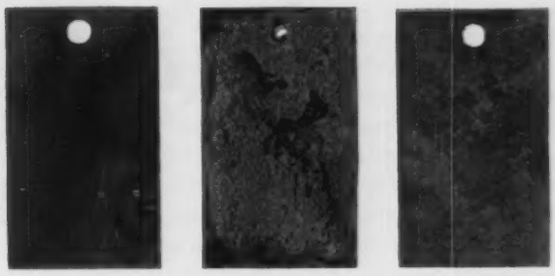

Fig. 7 Fig. 8 Fig. 9

Fig. 7—Detector plate before exposure
Fig. 8—Detector plate (after exposing and before cleaning)
Fig. 9—Detector plate (exposed plate after special cleaning)

These are located under the water line in the steam drum. They prove very valuable in registering the corrosive effects of the water itself within the boiler proper. Unlike the rods, the plates can be inspected and replaced only when the boiler is down for cleaning.

Comparison of the rods with the plates is of very considerable value for detecting the carryovers of corrosive gases with the steam. This is extremely important in locating cause for corrosion in steam using equipments. It can only be corrected where the full conditioning of feedwaters for the removal of all corrosive constituents is in effect. This situation is registered by the rods alone and is only complete when these sensitized pieces of steel upon their removal and inspection are found free of corrosion. When this situation exists and corrosion occurs in steam consuming equipments, other sources of contaminating the heating system with corrosive gases must be located and eliminated.

The cost of the detector rods and plates, together with the holders, is relatively low and should form a part of every well-regulated set-up for controlling the treatment of boiler feedwaters. It is just another one of those developments of the Rice Organization that has for its objective the positive detection and correction of objectionable water conditions at a cost which represents the definite practical minimum.

Where full knowledge of this subject is available, and dependable methods for checking are at hand, there is no reason whatsoever for corrosion to take place within any equipment subject to the action of water impurities.

This development of the detector system is in line with the earlier announcement of *Phoscaloid* which is now proving such a successful substitute for commercial phosphates, and which at the new low price will greatly reduce the costs of preventing silica scale and hard sludge formations within boilers.

Another development of the Rice Organization which will directly reduce the hazards of treating with caustics will be discussed in an early issue of "Combustion."

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Your past experience in trying to keep your boilers free from scale and corrosion does not count against *us*.

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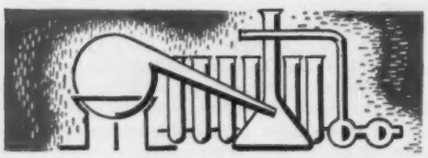
CAN BOILERS BE KEPT FREE FROM SCALE AND CORROSION?

OUR ANSWER IS "YES"

Is yours one of the numerous plants which has come to accept scale, corrosion, bagged and burned out tubes, and plugged feed lines as necessary evils with the water you have available?



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Adv. 15 B

EDITORIAL

FREDERICK ROLLINS LOW

1860-1936

WITH the death of F. R. Low at his home in Passaic, N. J., on Jan. 22, 1936, there passed an outstanding figure both in technical journalism and in the field of power engineering.

Often referred to as the dean of technical editors, Mr. Low had a career that spanned the most spectacular period in power development. When he entered the field Edison was still engaged in his pioneer work, destined to grow into the vast central station industry. Industrial power plant practice at that time was the embodiment of simplicity with its small capacity units, low steam pressures, slow-speed engines, hand firing and manual control of all operations. Although the thermodynamics of steam had been expounded by a few authoritative writers, very little had been reduced to practice.

It was Mr. Low's part and privilege, as an editor, to record each advance in practice, to interpret its influence and to guide opinion. He witnessed the rise of the steam turbine, the development of pulverized coal firing and of stokers, the employment of ever increasing steam pressures and temperatures, the application of electric drive to industry, various phases of automatic control and the employment of economics in power plant design and operation.

In the earlier days his was a virile influence for education among the operating men. To this purpose he directed much of his writing and also gave his time unstintingly to lectures before operating groups. Inasmuch as his technical education was self-taught, he had acquired a faculty of explaining technical problems with the utmost clarity, which was an asset in this particular work. There are many men now holding positions of responsibility in the power plant field who, in large measure, attribute their advancement to the assistance and encouragement rendered by Mr. Low in their younger years.

An ardent exponent of furthering safety through licensing and enforced inspection, he was long active in promoting legislation to this end. He was a moving spirit in the development of the A.S.M.E. Power Test Codes and the Boiler Code, both of which committees he served many years as chairman. In recognition of his long and distinguished service to the American Society of Mechanical Engineers he was elected its president in 1924 and shortly thereafter was made an honorary member of the Institution of Mechanical Engineers (Great Britain). Rensselaer Polytechnic Institute conferred upon him the degree of Doctor of Engineering.

As an editor Mr. Low was fearless. Never prone to snap judgment, he was always careful to make sure of his facts and the soundness of his premise, but once so assured, he brooked no interference nor permitted any influence from within or without to swerve him from the course he deemed to be in the interest of the profession and the field. Yet, withall, he was ever tactful, courteous and considerate of others' views.

During his active years Mr. Low had as wide a circle of friends and admirers among engineers of all classes as any man in the field. To his associates he endeared himself through his human qualities, his inspiration and his independent spirit. Always considerate and thoughtful of those about him, he delighted in doing the little things that count so much in personal relations.

It was most unfortunate that shortly after his retirement as Editor of *Power* in 1930, a long and painful illness overtook him and confined him to bed almost continuously until his death. It thus prevented him from fully enjoying in retrospect a long and fruitful career with its wealth of personal associations.

To his former associates, both in editorial work and in society affairs his passing is a personal loss. In the field at large his memory will long remain.

It was the writer's privilege to have been associated intimately with Fred Low for over twenty years and to have known and admired him as a man as well as an editor and an engineer.

A. D. Blake

Editor

Modernizing the Conners Creek Power Plant—IV

Plant Operating Cycle and Heat Balance

By SABIN CROCKER
Engineer, The Detroit Edison Company

The first article of this series of six appeared in the November issue and dealt with the economic considerations involved in the rebuilding program; the second described the stokers and development of their combustion air control; the third dealt with the steam-generating equipment; and the present installment discusses the plant operating cycle, heat balance and auxiliaries. That in the March issue will be devoted to the station piping in which welding is extensively employed. Among the problems encountered in the application of welding to high-pressure piping were refinements in procedure, supervisory control, simplification of piping layout, and design details, and the development of an induction method of stress relieving welds. These and other features will be fully discussed.

IN looking back over twenty years' history of central station development, progress in the art of power production is manifest in no more spectacular way than through the rapid increase of pressures and temperatures from the rather uniform levels extending through the first two decades of the twentieth century. This steep rise has been accompanied by a swing to regenerative feed heating, re-superheating in some cases, and the use of heat-saving appliances such as economizers and air heaters. The net result has been a one-half decrease in fuel consumption with a corresponding increase in efficiency to a new level where diminishing returns forestall further marked improvement without a complete change to other methods of converting fuel energy into power.

At the time the old Conners Creek Plant was designed, large boilers with reasonably satisfactory underfeed stokers were already in actual use, and increasingly large horizontal-shaft turbine-generators were being offered by the manufacturers in lieu of the then prevalent vertical machines. Feedwater was being heated with auxiliary-exhaust steam obtained either from the turbines of steam-driven pumps and fans, or from the house-service generating units if electric drive was used for auxiliaries. Where economizers were installed feed temperatures of 160 to 170 F were regarded as the optimum, and even without economizers temperatures did not exceed 200 to 210 F at the very maximum. As late as the December 1921 Power Waste Session of the A.S.M.E. American engineers were chided for the low operating pressures and temperatures still prevalent at that time. According to the recommendations in the report of the Super-Power Survey released in 1921,[1] throttle-steam conditions of 300-lb gage and 230 F degrees of superheat (about 650 F total temperature) were set forth as the optimum of that day. It is an interesting commentary that few of the engineers participating in that Power Waste Session agreed that these conditions were practicable for American plants in the then immediate future.

The foregoing facts are recounted to emphasize the point that old Conners Creek was designed and built prior to the era of rapid strides in plant operating cycles which led to the higher level of efficiencies obtaining today. The improvements now practicable were so marked that their immediate adoption seemed warranted in order to take advantage of them during as long a period as possible before they in turn become obsolete. Furthermore, as mentioned previously, these same improvements in plant process were effected through the installation of new equipment also having pronounced advantages in ease of operation, ruggedness for quick starting and general reliability, all of which features are of decided value in supplying dependable service to customers although not susceptible to exact evaluation.

[1] Professional Paper No. 123, U. S. Geological Survey, Dept of Interior.

Comparison of Old and New Plant Cycles

The thermal results obtained at Conners Creek before and after rebuilding are summarized in Table X, while the flow diagrams for the old and the rebuilt plant are shown in Figs. 29, 30 and 31. Although the figures for the new plant cover only twelve months' operation, and somewhat better results may be obtained eventually, it is interesting to note that they already show indications of a lower heat rate than was calculated in design.

Auxiliary Systems

In contrasting the new plant process with the old, some explanation of the differences in auxiliary-power supply and feed-heating arrangements is called for. In the old plant feedwater was heated in a barometric-condenser system with exhaust steam from house alternators and steam-driven boiler-feed pumps. An

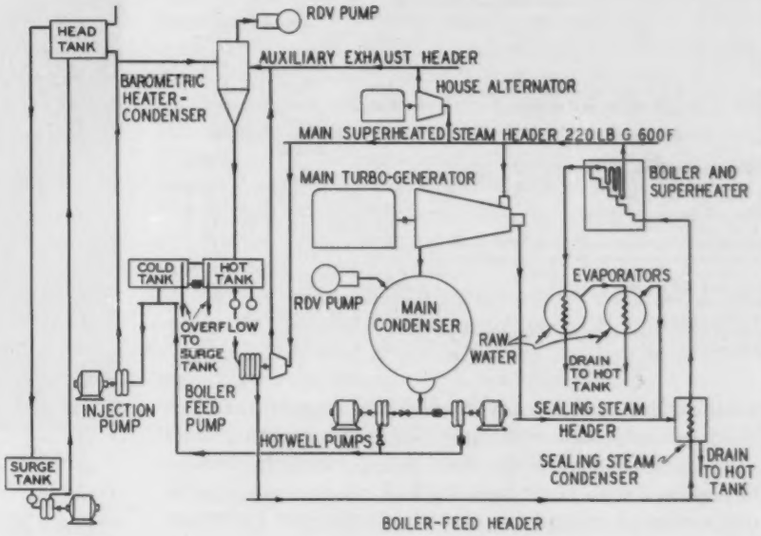


Fig. 29—Flow diagram of old plant

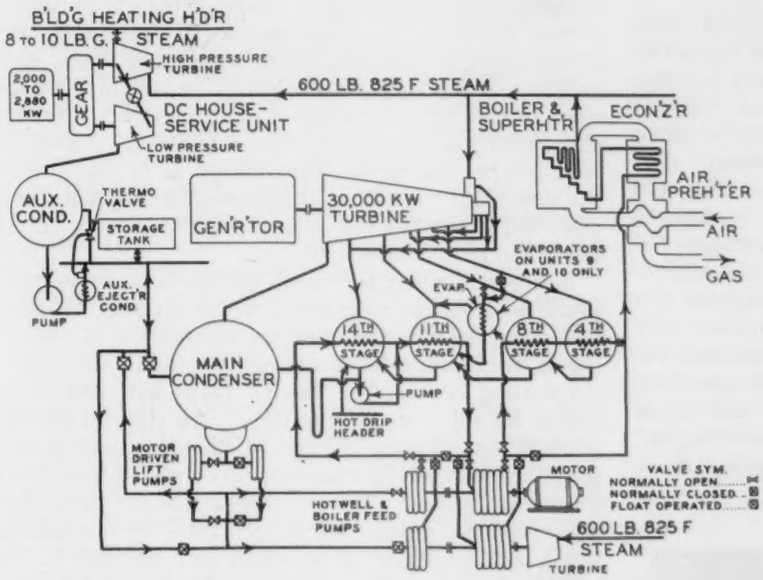


Fig. 30—Flow diagram of new 30,000-kw units

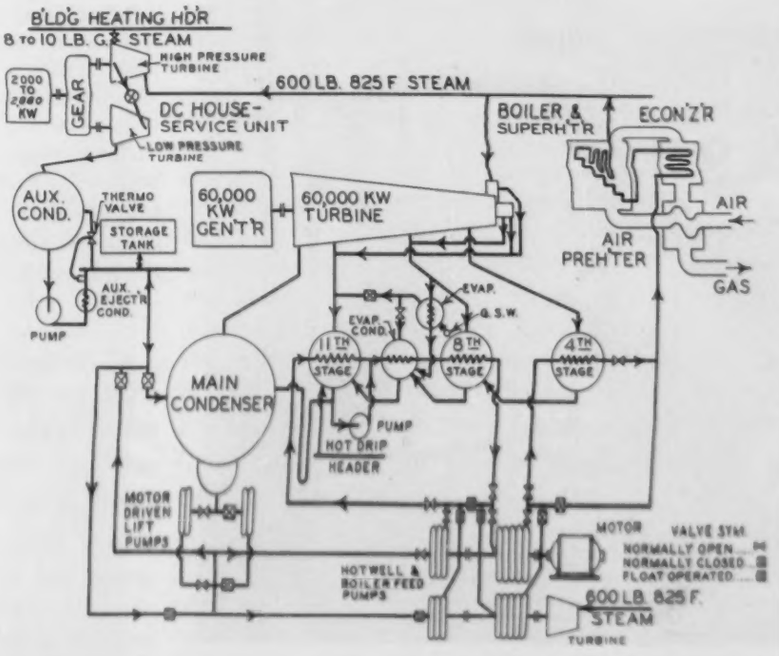


Fig. 31—Flow diagram of new 60,000-kw units

TABLE X

COMPARATIVE PERFORMANCE—OLD AND NEW PLANTS
AVERAGE VALUES

	Old Plant	New Plant Design	New Plant Year of 1935
Steam pressure, lb per sq in. gage, at throttle	220	600	611
Steam temperature, F, at throttle	600	825	832
Btu per net kwhr	19,000	Below 12,800	12,560
Station steam rate, lb per net kwhr	13	Below 10	9.8
Lb coal per net kwhr	1.46	1.00	0.95
Boiler efficiency, per cent	78	86	85.9
CO_2 at boiler outlet	14.5	15.0 to 15.7	15.2
Feedwater temperature leaving heaters, F	190	330	356
Feedwater temperature leaving economizer, F	none	373	398
Preheated air temperature, F	none	390	353
Stack temperature, F	650	325	297
Per cent auxiliary power	3.2	4.3 ultimate	4.8
Plant thermal efficiency, per cent, based on net output	18	26.5	27.2

additional fifteen to twenty degrees F of temperature was picked up in so-called sealing-steam condensers placed in the circuit between the feed pumps and the boilers and supplied with shaft-packing leak-off and evaporator vapor collected around the plant by a pipe line known as the "sealing-steam header."

The desired temperature of the feedwater was maintained by juggling the back pressure of the auxiliaries and by a "put and take" exchange of power between the house-service bus and the main-unit bus, through which the load on the house alternators could be varied to give the requisite amount of exhaust steam. The house alternators were operated on hand throttle so as to take whatever electrical load was required to balance with exhaust-steam requirements for feed heating. Direct current for driving adjustable-speed motors was obtained from a d-c bus supplied by motor-generator sets operated as units with individual house alternators, or from transfer sets between the main-unit bus and the d-c house-service bus. Other systems of interconnection for exchange of load between main units and house alternators were afforded through additional switch gear, and operating practice in this respect varied from time to time.

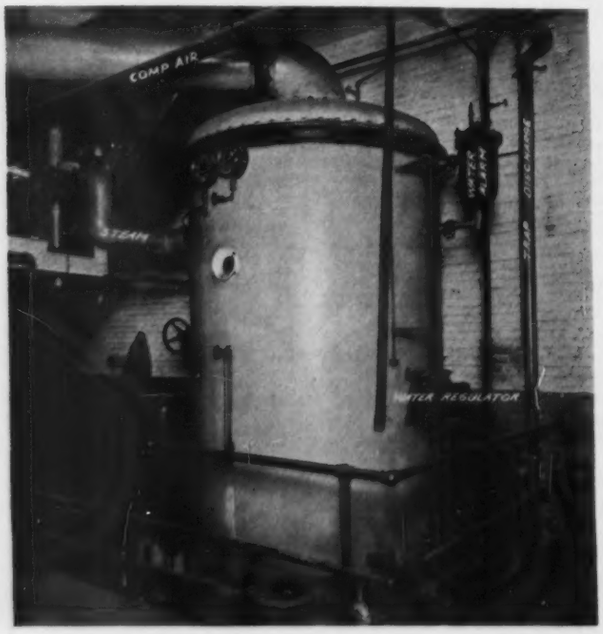


Fig. 32—Original single-effect evaporator in old plant

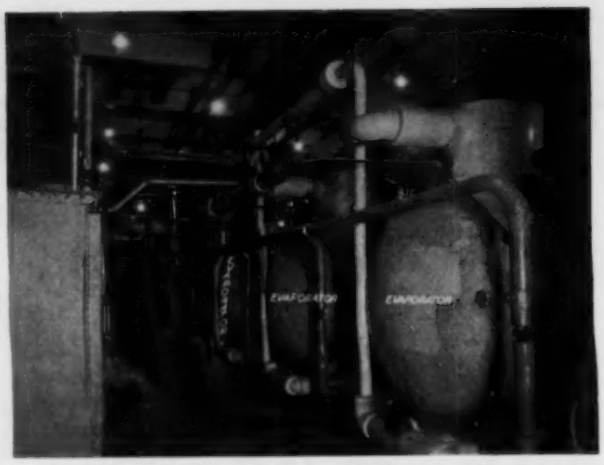


Fig. 33—Twin set of double-effect evaporators installed in old plant about 1920

Those auxiliaries whose uninterrupted running was essential to plant operation were all driven by direct-current motors or by steam turbines in the case of some of the boiler-feed pumps, while auxiliaries whose stoppage would not immediately affect the rest of the plant were driven by alternating-current motors. Although this system was workable to a satisfactory degree, its heat balance was not self-regulating as in the case of the new plant. The heat balance of the old plant was described in some detail in an A.S.M.E. paper by C. H. Berry and F. E. Moreton.[2]

In the new plant feedwater will be heated by steam extracted from the main units, which permits the use of bled-steam evaporators and the elimination of the old barometric condensers along with the house alternators. Alternating current for driving boiler-feed pumps, as well as for those auxiliaries that can be stopped without immediately affecting the rest of the plant, will be supplied by house-service transformers energized from Essex Switching Station. Direct current for driving adjustable-speed d-c motors will be generated by condensing, steam-turbine-driven units which can be bled to the building-heating system. Motor-generators will be used for direct-current reserve, either standing or running, but will not be counted on for regular d-c supply. All essential auxiliaries will be direct-current driven with the exception of one boiler-feed pump per main unit which will be driven by an a-c slip-ring motor. Quick-starting, steam-driven, boiler-feed pumps, one per main unit, will be installed for emergency use only, with their exhaust steam going either to atmosphere or to the main condenser since their restricted use will not justify using the exhaust for feed heating.

Evaporators

At the outset, that is between 1915 to 1920, the old plant was equipped with two single-effect evaporators, one of which is shown in Fig. 32, operating on live saturated steam and each having a nominal rated capacity of 12,000 lb of vapor per hour, not actually realized in service due to poor design. These evaporators, which had an internal steam drum with 278 two-inch diameter charcoal-iron tubes $42^1/_2$ in. long installed in a vertical position, were not well adapted for temperature

[2] A.S.M.E. *Transactions* 1921 and *Mechanical Engineering*, Jan. 1922.

descaling, hence could not be kept up to their rated output for any length of time without a shut-down for manual scraping. It was frequently necessary to remove the manhole covers to get inside the shells for the purpose of turbining scale out of the 278 straight tubes—a decidedly messy job.

When in 1920, due to the extension of the plant, it became necessary to add more evaporator capacity the unsatisfactory behavior of the original equipment dictated its replacement with a superior design having the requisite output over long periods with only temperature descaling. At that time a twin set of double-effect Reilly-coil evaporators, see Fig. 33, were installed which had a guaranteed total net output of 21,000 lb per hr when the first-effect coils were supplied with saturated steam at approximately boiler pressure. Raw-water makeup was preheated in an open heater from whence it was pumped into the evaporator shells through float-operated valves. Vapor from the second-effect shells was delivered to the plant sealing-steam header at a pressure slightly above atmospheric and condensed in Reilly-coil feedwater heaters placed in the risers from the feed pumps to the boilers as shown in the flow diagram of Fig. 29. About 25 per cent of the second-effect vapor, however, was diverted for preheating the raw-water feed. Operating under these conditions the net makeup actually obtainable on test exceeded 30,000 lb per hr without excessive carry-over. In case of abnormally heavy demand the evaporators could be operated single effect with a considerable increase in output. This arrangement proved entirely adequate for the old plant, although not as efficient as the bled-steam evaporator cycle evolved during the 1920's. Temperature descaling was usually done once a day and scraping or manual descaling once every three months.

In the rebuilt station each main turbine, with the exception of Unit 8, will be equipped with an evaporator to operate on bled steam. Two 30,000-kw units, Nos. 9 and 10, have been arranged to bleed steam to two of the old evaporators which have been moved to positions nearer the turbines but still located in the condenser room adjacent to the east wall. Fig. 34 shows one of these evaporator units as installed with Unit 9. Doors are provided in the wall at the back of the evaporator to permit withdrawal of the tube bundle from the shell into the ash aisle where cleaning or repair operations may be performed. The two old evaporators together are capable of producing makeup amounting to 1.3 per cent based on the steam requirements of the three 30,000-kw units when supplied with steam bled from the 8th turbine stages. If the steam supply is taken from the 4th turbine stages the makeup capacity is increased to 1.6 per cent. Actual operation of the plant to date has required an average makeup of less than 1.2 per cent.

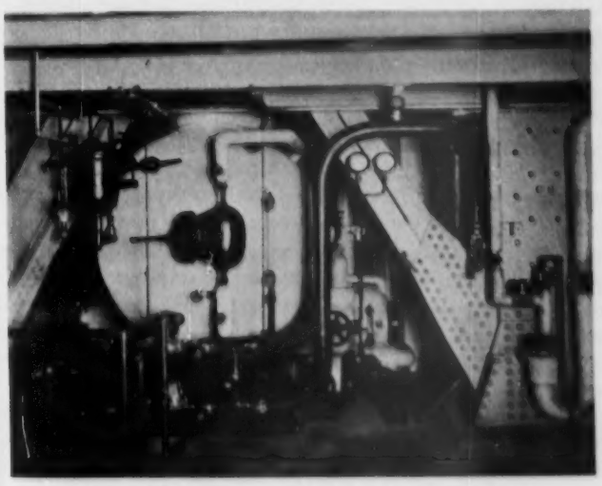


Fig. 34—Evaporator installed with Unit 9

The first 60,000-kw unit will be equipped with an evaporator of the bent-tube type, capable of producing 9250 lb per hr, or 1.5 per cent of makeup, when supplied with steam from the 8th turbine stage and discharging vapor to the evaporator condenser. If the distilled vapor is condensed in the 11th-stage heater the evaporator capacity will increase to 1.8 per cent.

The raw water from which the makeup is distilled is taken from the Detroit River and contains impurities in parts per million about as follows:

Total solids, ppm	190
Dissolved solids, ppm	134
Turbidity, suspended solids, organic and inorganic, ppm	120

After distillation the makeup will contain not more than 5 ppm of impurities.

Choice of Plant Cycle

Several factors were involved in selecting the operating cycle for the rebuilt plant, among which were, (a) determining the most commercially advantageous steam conditions; (b) deciding whether to superpose or rebuild; (c) choosing between a-c and d-c drive for auxiliaries, and the best source of such power. All of these problems were subjected to a series of economic studies during the years just preceding the inception of rebuilding, and solutions worked out which seemed best suited to the particular conditions obtaining at Conners Creek, due consideration being given to intangibles not subject to exact evaluation. The decisions reached, with some of the principal reasons for making them, are recounted in what follows.

Steam Conditions

When the project of rebuilding the Conners Creek Station was undertaken one of the first questions to be settled was that of initial steam conditions for the main turbines. A study was made to determine the probable results with a regenerative cycle under three different conditions of pressure and temperature which were: 400-lb gage at 700 F, 400-lb gage at 825 F and 600-lb gage at 825 F. Temperatures less than 825 F at 600-lb gage were not considered since their use would require the adoption of some form of reheating and it was felt that equally good commercial efficiency could be obtained with a simple regenerative cycle without the complication in design and operation that attends reheating. The economics of steam conditions of about 400 lb at 700 F have been so well established by the experience of the last few years that there was no point in considering lesser pressures and temperatures for this project. On the other hand, the Company's experimental work with 1000 and 1100 F steam at Delray and Trenton Channel, while satisfactorily encouraging and instructive, have not as yet led to a commercial development which would justify the design of an entire plant for steam at that temperature. Construction materials suitable for using 1000 F at the throttle were, and still are, so expensive that it was a foregone conclusion that a

plant for 1000 F could not compete commercially with those designed for lower temperatures. The cost information available at the time this decision was made indicated that a temperature of about 850 F would be the economic optimum for a plant being built at that stage of metallurgical development.

With 850 F established as the maximum temperature at the superheater outlet it was decided to study the use of steam at 825 F and 400-lb gage at the throttle and also at the highest pressure permissible with reference to moisture in the turbine exhaust without intermediate reheating. This latter pressure at the time of the study was considered by the turbine manufacturer to fall at about 600-lb gage As a result of the study of these three schemes it was decided to proceed with the design and construction of a plant for turbine throttle steam conditions of 825 F at 600-lb gage.

Rebuild vs Superpose

As mentioned in the November installment of this series under "Prime Movers and Firm Capacity," decision to install new machines rather than to superpose high-pressure units on the old plant was made after extensive study of the superposing scheme. The old turbines were not built for extraction operation and the cost of new high-pressure shells providing internal bleeder passages and outlets is prohibitive. In view of the inability to extract from the old turbines, some system of feed heating with auxiliary exhaust would have been required.

One scheme under consideration involved retention of the old barometric-condenser system which presents operating problems that do not compare advantageously with extraction heating. Furthermore, the barometrics took their steam from the house-alternator exhaust and these latter units had been more or less troublesome and were about worn out.

In another superposing scheme a three-stage feed-heating cycle was worked out as follows: A high-pressure heater would be supplied with steam bled from the exhaust of the high-pressure turbine; the intermediate-pressure heater would take steam from the exhaust of a turbine-driven boiler-feed pump and from the building-heating header which normally would be supplied with steam bled from d-c house-service units; the low-pressure heater would be designed to condense the turbine-shaft-packing leak-off and the evaporator vapor from the second effect of the old-plant make-up system. This combination would be decidedly more complicated than the clean-cut method afforded by the replacement scheme. It seemed inevitable that the operating labor and maintenance would be considerably higher for superposing than for replacement.

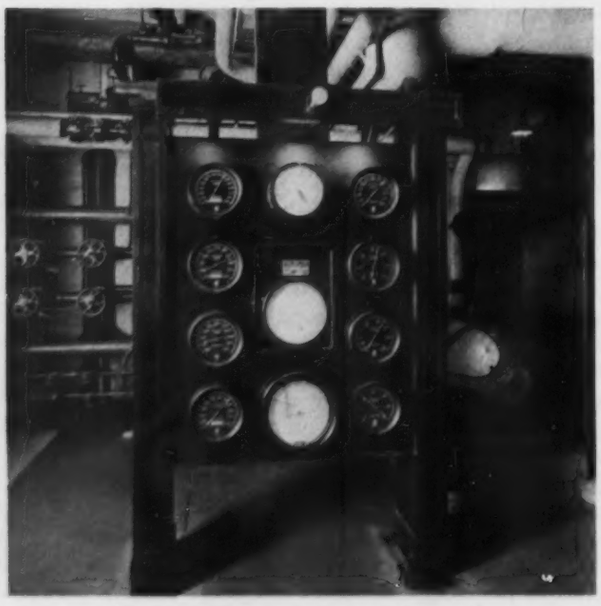


Fig. 35—Heater gage board—Unit 9

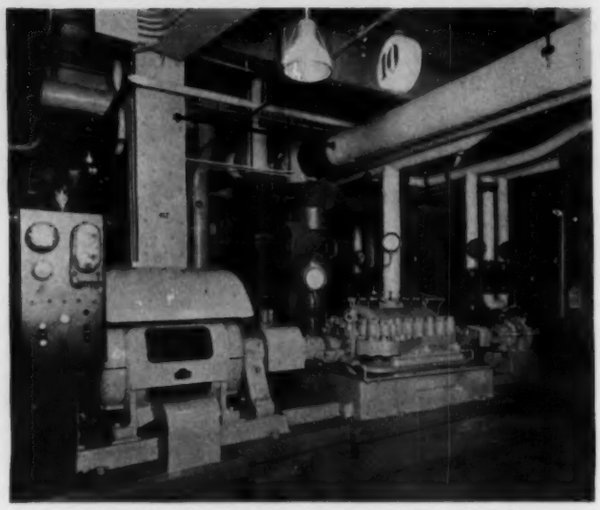


Fig. 36—Motor-driven boiler-feed pump installed with Unit 10

Auxiliary Drive

The auxiliary-power system at Conners Creek is like the one at Delray Power House No. 3 in many ways. Since the use of direct-current drive for auxiliaries, while admittedly good from the standpoint of speed control and simplicity of operation, has been questioned on the score of supposed higher operating and investment costs, the possible merit of applying alternating-current drive to feed pumps, fans, circulators and the like was reconsidered for Conners Creek. For systems of comparable flexibility, these studies failed to show on most items of auxiliary equipment sufficient saving in fixed charges or operating costs to warrant the use of alternating current drive, especially in the face of the proved operating advantages of d-c drive.

A further factor in favor of direct-current drive for essential auxiliaries in this particular case was the ability to re-use many such units from the old plant. Circulators, vacuum pumps, lift pumps (old hotwell pumps) and several more have been reclaimed along with their former drives for use in the new plant. The new stokers, with their forced- and induced-draft fans are driven by new d-c motors, while the new clinker grinders are driven by the same d-c motors formerly used with the old stokers. The direct-current house-service load in the completed station (330,000 kw) will approximate 9500 kw at full plant load.

The most important users of alternating current in the new plant are the motor-driven boiler-feed pumps. The advantages of putting this essential auxiliary on a-c drive as better suiting the power and normal speed

requirements of the pump, are related under "Feed Pumps and Drives." Coal-handling systems, house lighting, air compressors, machine tools and many miscellaneous small items combine to give an expected a-c house load of about 5000 kw in the ultimate plant.

Details of New Plant Cycle

Now that the principal features of the plant have been outlined, a detailed description of the new-plant operating cycle can be undertaken along with an account of minor differences between the 30,000-kw and the 60,000-kw sections. Figs. 30 and 31 are diagrams of the plant cycles for the 30,000-kw and 60,000-kw units respectively.

Regenerative Turbine Cycle

Fundamentally the operating cycles of the 30,000-kw and 60,000-kw units are the same. The turbines function on the regenerative cycle, heating feedwater in closed surface-type heaters. Steam condensed in the main condenser is pumped by a lift pump at about 50-lb pressure into the suction of the hotwell pump. The hotwell pump discharges at about 175-lb pressure through the low-pressure feedwater heaters into the suction of the boiler-feed pump. This pump, in turn, discharges at about 780-lb pressure through the high-pressure heaters into the economizer and boiler. These pumps are described in detail later in this installment under "Feed Pumps and Drives."

Steam condensed in the heaters is removed by a cascading system in which the drains from each heater are flashed consecutively into the next-lower-pressure heater shell. It was found economical, however, to pump the accumulated drains from the lowest-pressure heater back into the condensate stream between the two low-pressure heaters rather than to flash them into the main condenser. By-passes are installed so that the drains from all heaters can pass directly to the suction of the heater-drains pump during the turbine-starting period when the pressure difference between the heater shells is too small to operate the cascade. Also a water seal is provided between the lowest-pressure heater and main condenser which will automatically pass the heater drains into the condenser in case the water level rises above a predetermined point in the heater hotwell, due either to failure or improper operation of the heater-drains pump.

The turbine shafts are equipped with high- and low-tooth labyrinth packings at the high-pressure end of the machines. The packing is arranged in stages with a leak-off following each group of packing rings. The intermediate leak-offs are piped into the turbine. The outer, or atmospheric, leak-off which is maintained at a pressure of about one-pound gage by means of a manually-operated valve, discharges its steam into the lowest-pressure feedwater heater. Steam leakage from the admission valves, estimated at 500 lb per hr, joins the outer shaft-packing leak-off and is condensed in the lowest-pressure heater.

The four feedwater heaters on each of the 30,000-kw units extract steam from the fourth, eighth, eleventh and fourteenth turbine stages. The heaters are of the four-pass floating-head type with locked-head design of cover plates for the water boxes of the two heaters in the boiler-feed circuit. Tube bundles are removable. In the 4th- and 8th-stage heaters baffling is provided to direct the entering superheated steam against the tubes of the last water pass so as to reduce or eliminate any terminal difference, and suitable baffling is provided for the withdrawal of air near the bottom of each heater. Air bled off is cascaded through successive heaters to the main condenser. Steam and water connections to the four heaters are shown in Fig. 30. Fig. 35 shows a gage board installed to indicate the steam pressure, water flow and water temperature in each of the four heaters.

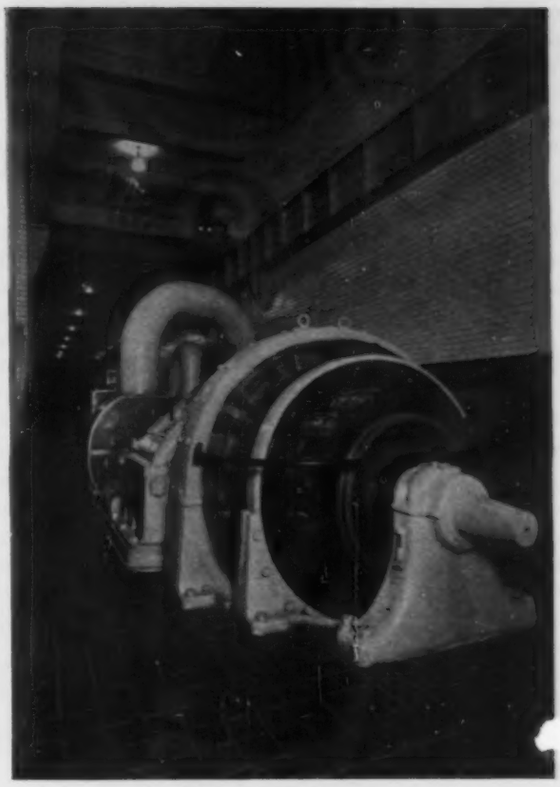


Fig. 37—2000-kw d-c house-service unit

While the feedwater-heating cycle of the 60,000-kw units is essentially the same as that of the 30,000-kw units, only three of the four stages operate directly upon extracted steam which is bled from the turbine at the fourth, eighth and eleventh stages. The other stage of feedwater heating lies between the eighth- and eleventh-stage heaters and actually is an evaporator-vapor condenser. The evaporator operates on steam bled from the eighth stage as previously explained under "Evaporators."

The use of only three stages of bleeding on the 60,000-kw units results from the fact that the turbine has only 14 stages as compared with 18 stages in the 30,000-kw machines. In buying the 60,000-kw machines, proposals were offered on units of 14 and 17 stages. While the heat consumption of the 17-stage machine, calculated for an annual plant factor of 45 per cent, was less than that of the 14-stage unit, the heat saved was not enough to pay fixed charges on the additional cost of the extra stages. The 14-stage unit was selected, therefore, since the advantages of mechanical ruggedness and better adaptability to the space limitations of old 45,000-kw Units 4 and 6 also lay with the shorter shaft turbine. Since the pressure drop per stage is in consequence somewhat greater in the 60's than in the 30's, a fourth stage of

extraction heating would produce a feedwater temperature approaching 405 F at maximum turbine load, which is considered somewhat too high for good efficiency of the economizer and air heater equipment in the boiler room. Furthermore, the thermal saving effected by a fourth stage of bleeding would not, in the case of the 14-stage 60's, pay the fixed charges on the extra heater which would be designed for boiler-feed pressure.

The thermal disadvantage of having only three stages of extraction feedwater heating is largely offset in this particular case by the use of the evaporator condenser which is a relatively inexpensive piece of equipment. Whether an evaporator condenser justifies itself or not depends upon the location of the available bleed points throughout the expansion range of the turbine. In some cases the introduction of an evaporator condenser effects a better distribution of bled steam among the extraction stages, while in other cases less favorable distribution results. For the 60,000-kw units at Conners Creek the relative thermal advantage of the evaporator condenser can be indicated by the following calculated heat savings:

Bleeding Arrangement	Saving over 3-Stage Bleeding, Btu per Kwhr
Three stage	0
Three stage plus evaporator condenser	26
Four stage	40

Fig. 31 shows the steam and water connections to the feedwater heaters of the 60,000-kw unit.

Each main unit is expected to handle at least its proportionate share of auxiliary condensate and miscellaneous plant drips, which enter the circuit through the shells of the low-pressure heaters. These systems are discussed in detail later in this installment under the headings "Hot-Drip System" and "Sealing-Water System."

Calculated feedwater temperature data at maximum turbine load are given by heater stages in Table XI for both the 30,000 and 60,000-kw machines. The terminal differences expected at the outlet of the heaters refer to saturation temperature of the bled steam within the heater shell and the negative differences shown for the fourth-stage heaters are made possible through providing baffles to take advantage of the considerable amount of superheat in steam entering the heater.

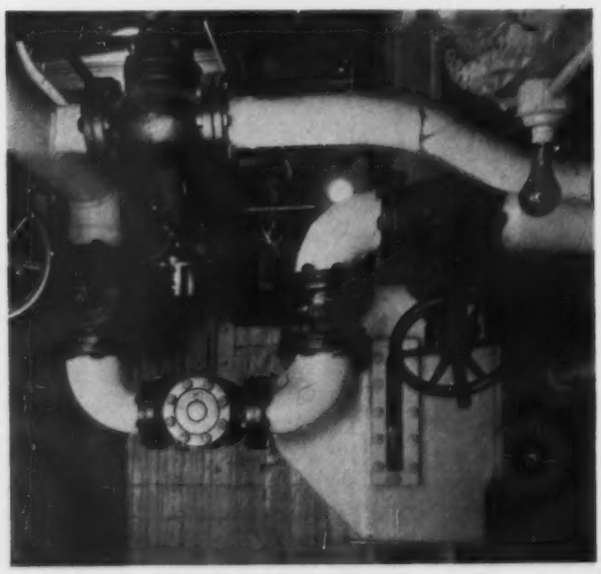


Fig. 38—Chronometer valve and float chamber—Unit 8

TABLE XI

CALCULATED FEEDWATER TEMPERATURE DATA AT MAXIMUM TURBINE LOAD—REBUILT PLANT

	Heater	Temperature Leaving Heater, F	Temperature Rise in Heater, F	Terminal Difference, F
30,000-kw unit	Condenser hotwell	79		
	14th stage	182.5	103.5	5
	11th stage	259.2	75.2*	2
	8th stage	323.1	63.9	0
	4th stage	388.4	65.3	−3
60,000-kw unit	Condenser hotwell	79		
	11th stage	181.9	102.9	5
	Evap Condenser	209.1	25.7*	5
	8th stage	275.7	66.6	2
	4th stage	367.9	92.2	−2

* Mixing of heater drains with main condensate accounts for 1.5 deg rise.

Feed Pumps and Drives

The arrangement of condensate and boiler feed pumps used at both Trenton Channel and Delray Power House No. 3 is so well liked by the operating staff that it was adopted for the new units at Conners Creek. Different sizes of pumps will be used on the 30,000-kw and 60,000-kw machines, but the pumping systems will be similar. Duplicate d-c motor-driven pumps will be installed in each hotwell pit. These units, known as lift pumps, were converted from the old hotwell pumps by fitting them with new first-stage impellers. Running at constant speed, it is their function to discharge condensate from the condenser hotwell into the suction of the hotwell pump. The lift pumps have sufficient head to discharge water to the condensate-storage system during periods of increasing plant load. The hotwell pump discharges water through the 14th- and 11th-stage heaters on the 30,000-kw units into the suction of the boiler-feed pump. On the 60,000-kw unit the hotwell pump discharges through the 11th-stage heater, evaporator condenser and 8th-stage heater into the suction of the boiler-feed pump.

The boiler-feed pump discharges through the 8th- and 4th-stage heaters of the 30,000-kw unit, and through the fourth stage only of the 60,000-kw unit, into the boiler-feed header. In all cases the hotwell pump and boiler-feed pump, which are coupled together and mounted on a common base plate, are powered by the same driver. Duplicate hotwell and boiler-feed pumps are installed for each main unit, the one for normal operation being driven by a slip-ring a-c motor and the other for standby by a rugged, quick-starting turbine arranged to exhaust either to atmosphere or to the main condenser. In emergencies either hotwell pump can take its suction directly from the condensate-storage system. Only one heater-drain pump, driven by an adjustable-speed d-c motor, is installed for each main unit.

This is the first installation of a-c motor drive for boiler-feed pumps in the Company's more recent plants. It previously has been Detroit Edison practice to use direct current on all essential auxiliaries, but in the present case the pumping head is so high that a pump speed in the region of 1800 rpm is necessary in order to keep within what was deemed a reasonable number of pump stages. Since at the same time commutation problems would limit the speed of a d-c motor to a maximum of about 1200 rpm for the power requirements involved, this type of drive was precluded without the use of a

speed-increasing gear which was undesirable from a standpoint of cost and space requirements. The possibility of a turbine drive, exhausting to a feedwater heater, also was studied but discarded when it became apparent that operation of the feed-pump turbine might be unstable due to the variation of its back pressure with main-turbine load.

Consequently, an a-c slip-ring motor drive at full-load speed of 1770 rpm was adopted for feed pumps in the rebuilt plant. The high speed resulted in a short-shaft pump, and it has been found in actual operation that the sloping speed characteristic of the slip-ring motor is of real benefit in the parallel operation of these units. A view of the motor-driven hotwell and boiler-feed pumps installed with Unit 10 is shown in Fig. 36.

Boiler-Room Heat Balance

Heat-absorbing surface in the boiler room consists of air heater, economizer, saturated-steam boiler with water walls and superheater units. Mention of the unusual design features of these pieces of equipment will be found in the January installment under "Boilers and Steam-Generating Equipment." Data regarding flue-gas analysis and air, gas and water temperatures will be given here however.

The air heaters are designed for an average air inlet temperature of 85 F, to produce a preheated air temperature ranging from 340 to 420 F depending on boiler rating. Preheated air is delivered to underfeed stokers through the sectionalized control device described in the December installment under "Combustion-Air Control." While it was expected that with this combustion system, at 200,000 lb per hr evaporation, CO_2 values up to 16.1 per cent and 15.5 per cent would be attained at the end of the superheater pass and at the boiler outlet respectively, observations made thus far have shown CO_2 percentages of 17.5 and 15.2 at these locations for the same output.

As the products of combustion progress through the boiler they give up their heat to the saturated-steam surface and to the superheater which is of a special design intended to maintain a nearly constant steam temperature at varying boiler outputs. The gas temperature at the boiler outlet varies from 525 to 853 F depending on the coal burning rate. From the boiler the gas passes to the economizer and thence to the air heater.

The economizer is designed for an average incoming water temperature of 330 F, under which condition it is expected to heat the water to a final temperature ranging from 373 F to 402 F depending on the rate of boiler output. Because of certain changes in the choice of turbines and the method of plant operation after the boiler design was established, the average feedwater temperature from the 30,000-kw units to the economizer runs about 356 F. While this will be somewhat lower with the 60,000-kw units in operation, it will even then be higher than the originally expected average of 330 F. Under design conditions the gas temperature leaving the economizer should vary with load between 385 and 608 F. In passing through the air heater the gas gives up some of its sensible heat to the air used for combustion, and at the air heater outlet the gas temperature should range from 271 at low firing rates to 360 F at maximum output.

With this set-up of boiler-room equipment an overall efficiency as high as 89.8 per cent is anticipated for the optimum point occurring with a coal-burning rate of 16,000 lb per hr, while at maximum output, corresponding to 42,000 lb of coal per hr, an overall efficiency of 85.5 per cent is expected.

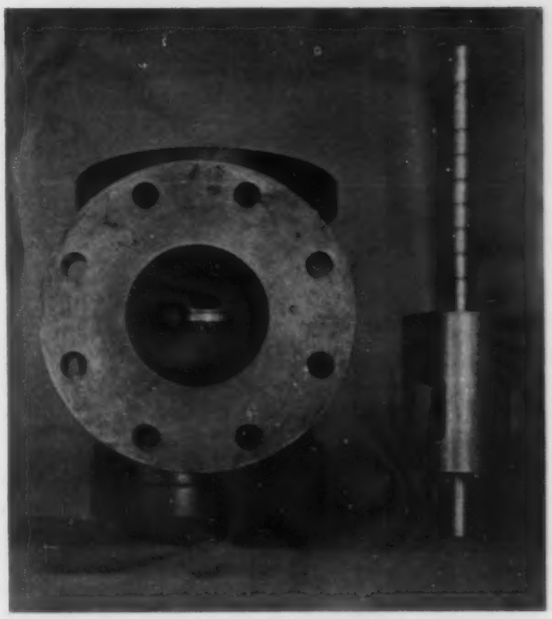


Fig. 39—Chronometer valve unassembled

House-Service Units

Direct current for house service is generated at 240 volts by turbine-driven geared d-c generators. For an ultimate plant of 330,000 kw five d-c machines are contemplated, one of 2000-kw capacity and four of 2880-kw capacity each. Motor-generator sets for conversion of ac from the main-station bus into dc provide the necessary standby. Fig. 37 shows the 2000-kw turbine-driven unit.

The house-service turbines are cross-compound units operating condensing, with arrangements to bleed steam at the crossover to the building-heating system at a normal pressure of 10-lb gage but adjustable over a range of pressures from 0 to 15-lb gage. Each low-pressure turbine is equipped with an automatic control valve which restricts its own admission so as to maintain a constant pressure at the bleed point, while flow of steam through the high-pressure admission valve is regulated by electrical load with the governor operating to maintain constant speed.[3]

Steam not extracted at the crossover passes on through the low-pressure barrel to the auxiliary condenser, from which an auxiliary hotwell pump removes the condensate and pumps it into the condensate-storage system. Each auxiliary condenser is equipped with a steam-jet air ejector, the inter- and after-condenser of which is cooled by the auxiliary condensate on its way to the storage system. Since the air ejector requires as much as 10,000 lb of water per hr for cooling and because there may be as little as 1000 lb of condensate per hour when the turbine is being bled heavily, a thermostatically-controlled make-up line is installed on the condenser. If the water temperature leaving the inter- and after-cooler exceeds a predetermined value the thermostatic makeup valve opens

[3] For a detailed account of this equipment see, "Revamping the Building-Heating System in the Modernization of Conners Creek," by Sabin Crocker, p. 25, *Heating, Piping and Air Conditioning* for January 1936.

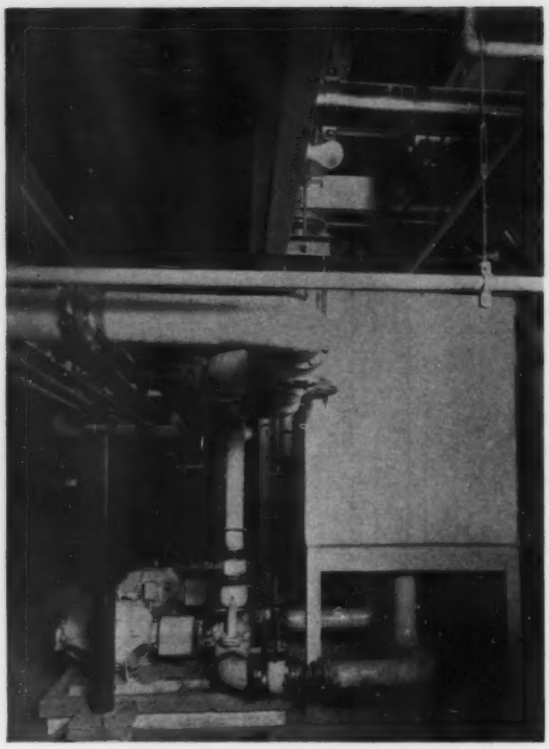


Fig. 40—Hot-drip tank and pumps

to provide the needed amount of cooling water. It is not the purpose of this arrangement to conserve the latent heat of the steam used by the air-ejector but rather, by raising the temperature of the condensate-storage system, to insure better deaeration of the auxiliary condensate as it enters the boiler-feed system through the main condenser. The generator of the 2000-kw set was taken from a motor-generator at Conners Creek while the generators for all of the 2880-kw units have been reclaimed from Delray Power House No. 2 and from substation motor-generators made available by changes in the direct-current system which supplies customers.

The alternating-current plant bus is now supplied from two 4000-kva house-service transformers which are energized from Essex Switching Station. The availability of this scheme is believed to be equal to or greater than that of a system of turbine-driven house alternators although the cost of the installation was considerably less. The use of shaft-end generators was precluded by the space limitations of the old turbine room.

Condensate-Storage System

Mention has already been made under the heading of "Feed Pumps and Drives" of the possibility of discharging water from the main-condenser hotwell to storage at times of increasing plant load. On the other hand, it is possible to replenish the supply of water in the hotwell at times of decreasing plant load through a float-controlled valve which also serves to admit the auxiliary condensate through the main condenser hotwell route to the boiler-feed circuit. Water reaching the hotwell through this connection enters the condenser through a perforated pipe located so as to spread the water out in thin sheets for the purpose of deaeration as will be described under "Condensers" in a later installment.

The interchange of condensate between the main condenser and storage system is regulated by the two so-called "chronometer" valves mentioned above which are actuated through floats and levers by change of water level in the condenser hotwell. If for any reason the hotwell water level goes higher than normal the high-level float actuates the valve between the lift-pump discharge and the condensate-storage system (see Figs. 30 or 31), thereby providing an outlet to storage which is independent of the boiler-feed system. In the same way, if the hotwell level falls below normal, as would occur during a reduction of plant load or during blowing of the safety valves, the low-level float mechanism opens the valve between the condenser shell and condensate-storage system to admit the necessary amount of reserve water. Under conditions of steady load a small flow of water through this valve into the main hotwell is to be expected as the normal course through which condensate from the auxiliary condenser returns to the boiler-feed circuit. In the winter, of course, much of the steam used to generate auxiliary power is condensed in the building-heating system and returned to the feedwater circuit as explained later in this installment under "Hot-Drip System."

These float-operated valves are called "chronometer valves" because of their special design which permits rather fine regulation. Fig. 38 shows one of these valves with its float chamber while Fig. 39 shows the valve body and ported piston disassembled. Sensitive response to change in water level is insured through the use of a large-size float in conjunction with a piston-type valve which uncovers its ports through rotating about the axis of the piston rather than reciprocating along the axis.

Hot-Drip System

There is installed in the rebuilt plant a "hot-drip system," the purpose of which is to collect all of the miscellaneous plant drips and return them into the boiler-feed circuit. The items of condensate involved and the method of disposing of them are as follows.

In an open pit dropped below the condenser-room floor there are pumps and a receiving tank, called the heating returns tank, which receives the building-heating condensate,[3] and sealing water from the following:

(1) Shaft seals on
  (a) main turbines
  (b) auxiliary turbines
  (c) boiler-feed pumps
  (d) hotwell pumps
  (e) heater-drains pumps

(2) Atmospheric-relief-valve seals on
  (a) main condensers
  (b) auxiliary condensers
  (c) low-pressure feedwater heaters
  (d) exhaust of boiler-feed-pump turbine

Condensate from the heating-returns tank is pumped by the heating-returns booster pumps into the hot-drip tanks which are located in the condenser room, (see Fig. 40). The hot-drip tanks also receive the discharge from high-pressure traps located on the main-steam piping, superheater, etc, as well as a portion of the condensate from the discharge of the hotwell pumps, which enters the hot-drip tank through spray nozzles and cools the trap discharges to a reasonable degree below 200 F.

These two receiving systems, i.e., heating-returns tank and hot-drip tanks collect all the miscellaneous condensate around the plant that can be saved. From the hot-drip tanks the mixture is pumped into a hot-drip header and thence into the shells of the lowest-pressure heaters of the main units. It is intended that the hot drips will be deaerated upon entrance into the heater shells by being spread out in a thin sheet or otherwise broken up to facilitate flashing.

Sealing-Water System

Sealing water for the new plant is supplied from head tanks installed in a gallery located at the bunker-room floor elevation. One head tank is installed for the first section and two additional tanks will be required for the second and third sections. These tanks, which are supplied with condensate from the hotwell pumps through float-operated valves, furnish sealing water for the main and auxiliary turbine shaft seals, and water-sealed atmospheric-relief valves. Spray water for the hot-drip tanks is taken from the discharge of the hotwell pumps through the small header that also supplies the sealing-water head tanks. In the old plant the sealing-water head tank is supplied from the surge pumps and floats on the same header as the new tank, from which it is separated by a sectionalizing valve. This old tank will be used for one of the three tanks in the ultimate rebuilt plant.

SIMULTANEOUS OPERATION OF NEW AND OLD PLANTS

In many respects the new and old units at Conners Creek are like two independent plants operating together temporarily under one roof. The main steam systems are entirely separate of one another, while each generator is connected to its own section of the Essex bus, partially isolated from the other sections by current-limiting reactors. There are, however, two important services that are common to the two sets of main equipment, namely, the a-c and the d-c house-service systems. It may be of interest to recount the temporary arrangements under which these services operate during this joint tenancy of the plant.

Alternating-current house service in the old plant is supplied from the house alternators or the house-service transformers, both of which feed into the 4800-volt a-c house bus. The a-c-driven auxiliaries in the new plant take their supply from this same bus so that a-c auxiliary power used in the new plant may actually be generated on the old house alternators. When the new plant is completed the a-c auxiliary power will normally be taken from the main units since all the a-c house service will then be carried on the transformers which are tied to the main units through switches at Essex Station.

The first new main unit was installed and running some months ahead of the new turbine-driven d-c generator. The d-c house bus is common to both the new and old plants, however, so that direct current for the new plant auxiliaries was generated in the old plant on motor-generator sets. Now that the new d-c machine is operating, its output is pooled with that of the motor-generators and it is possible to drive old-plant auxiliaries from the new section and vice versa. Ultimately only two to four motor-generators will be retained for stand-by service and the rebuilt plant will be self-supporting in the matter of direct-current supply.

Standby Capacity during New York's Partial Interruption of Service

In the reports of system trouble in New York on January 15, mention has been made of the standby services rendered to Hell Gate Station by the other system generating stations and outside ties. The reason that load was lost was due to the electrical damage at the Hell Gate Station which prevented immediate energizing of the buses at Hell Gate through tie lines from other sources. In spite of the prevailing impression that a large amount of load was lost, actually it did not exceed 10 per cent of the total system.

Upon the occurrence of the trouble Hudson Avenue Station which was carrying 400,000 kw immediately picked up all of the 60-cycle load to which its feeders had access which gave a 100,000-kw increase and then gradually, with the approach of the evening peak, carried the additional normal increments of load in the districts served by these feeders, making a total station load of 620,000 kw. The response to this sudden increase and further gradual increase was all done with stoker-fired boilers. Fifteen boilers were in operation, eight of them with zoned air control and seven without zoned air control. All boilers responded equally well in proportion to their capacity. Within the first minute the boilers picked up the largest single increment of load and then gradually responded to the further demands of the electrical system maintaining high ratings continuously throughout the emergency period with no difficulty whatsoever. Two 50,000-kilowatt units were called for when the trouble started, and were synchronized shortly thereafter. During the emergency period Hudson Avenue carried 83 per cent more load than the Brooklyn requirements demanded.

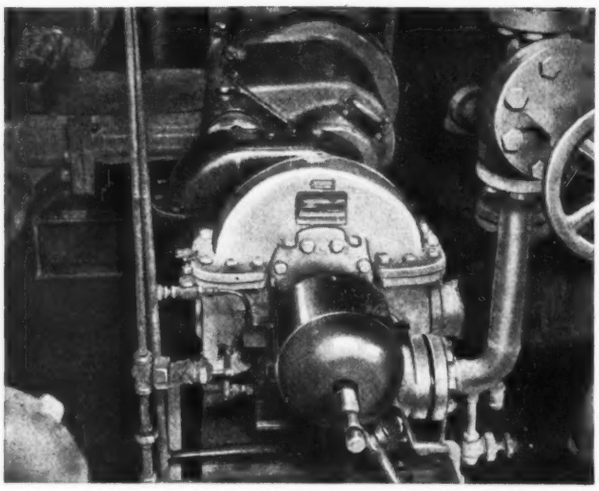
The seven boilers without zoned air control went from an average steaming rate of 195,000 lb of steam per hour at 4:15 p.m. to 315,000 lb of steam and later to 345,000 lb of steam. The eight boilers with zoned air control went from an average of 325,000 lb of steam per hour to an average of 450,000 lb of steam per hour and continued approximately at this rating as long as the demand existed. These eight boilers still had considerable reserve capacity which was not called on due to the limitations in the electrical outlet.

Appalachian Coals to Continue

Appalachian Coals, Inc., the pioneer regional coal sales agency, sacntioned by a decision of the U. S. Supreme Court, will continue operations, serving eight producing fields of Kentucky, Tennessee, Virginia and West Virginia, according to announcement from its headqu :ters in Cincinnati. The agency, deprived of its pricing functions until the Supreme Court rules on the Guffey Act, will maintain an organization for service along other lines. The announcement was prompted by inquiries, not only from coal producers but also from executives of agencies, patterned after the Appalachian plan, in other industries.

HERE'S WHY ... Adolph Coors Co.

Uses a G-E Gear-turbine for Driving a Pump



This compact, self-contained gear-turbine drives a boiler-feed pump in the plant of the Adolph Coors Company, brewers, at Golden, Colorado

HIGH PLANT ECONOMY

The Adolph Coors Company uses the clean—oil-free—exhaust steam for heating boiler-feed water. A clean heating system saves fuel and saves time which might otherwise be required for shutdowns for cleaning out the heating pipes. The *right* gear ratio permits both the turbine and the pump to rotate at their most efficient speeds—this helps to raise the plant efficiency.

RELIABILITY

The simple and quick-acting governing mechanism provides excellent boiler-feed-pressure regulation and assures reliability of the boiler-feed service. Since moving parts of the turbine are few; since an ample lubrication system is provided; and since gear and pinion are *accurately* matched, the turbine runs at any speed within its range, with minimum wear. Thus, dependable service is assured, and maintenance expense is kept very low. General Electric, Schenectady, N. Y.

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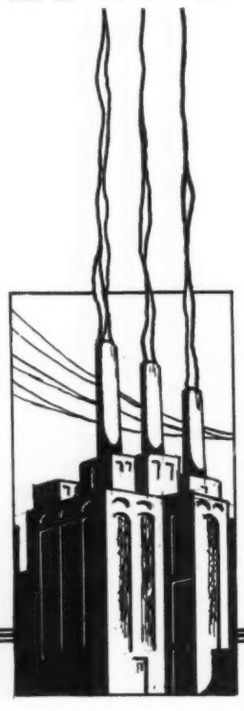

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Possibilities of Boilers with Forced Circulation*

By Dr. FRIEDRICH MUNZINGER, Berlin, Germany

A critical examination of the essential characteristics of the various types of boilers, including both forced and natural circulation, and the influence of high pressures on the design. Forced circulation is discussed at length and a distinction is made between it and forced flow. The present large number of boiler types is indicative of a transition period and the author endeavors to point out the lines along which future development is likely to proceed.

SCIENTIFIC research has greatly advanced the German boiler industry during the last decade and has contributed much to its comparatively quick catching up with American practice. It is, however, doubtful (and this applies perhaps also to other branches of the power-engineering field), if the purely scientific tendency in Germany has not been over-emphasized, while neglecting the element of practical design; for, as great as the importance of scientific research might be, too great an emphasis on it might lead to over-estimating the theoretical fine points, and to neglecting the paramount importance of good design.

Design and operation of tubular boilers have been greatly influenced during the last decade by research into the processes of combustion taking place in the furnace, and into natural circulation in boilers, by the introduction of forced circulation, the appearance on the market of steel with high tensile strength, and by the great advances in chemical water purification.

The object of the present paper is the investigation of the probable further development, with special reference to high-pressure boilers.

Steam of the highest pressures, which in America is now in comparatively frequent use, has, during the last year, made great progress also in Germany. On July 1, 1935 there were in Germany, under construction or in operation, about thirty-six stationary boilers for a pressure of more than 1000 lb per sq in. and with a maximum combined capacity of about $3^1/_2$ million pounds of steam per hour. Germany is probably the only country in which large boilers for a pressure of nearly 1500 lb per sq in. are successfully operating with chemically treated feedwater without the addition of condensate.

Influence of High Pressure on Design of Boilers with Natural Circulation

V-TYPE BOILERS. Many boiler designs have been created by accident or are due to outdated assumptions. The force of habit is frequently to blame for belated application of scientific knowledge. So, for instance, in the earlier days of the V-type boiler the feedwater was preheated in economizers to a limited extent only. As furnaces at that time did not operate with the present high CO_2 and only moderate flue gas velocities were being used, it was necessary to have large boiler heating surfaces, and, in consequence, from four to five boiler drums had to be used; the cost of which, with increasing pressure, was an important item. Gradually, the three-drum V-type boiler became the standard type. It was comparatively easy to maintain reliable circulation in it and this type still prevails in America even for very high pressures (see Fig. 1). In Germany the manufacture of two-drum boilers has been customary for the last 12 years. The first large German high-pressure boiler and nearly all its successors were of this type (see Figs. 2, 3, 4 and 5). Some companies use even only one upper drum and replace the lower drum by headers (Fig. 6). The preference given by American engineers to the three-drum type for high-pressure boilers is the more surprising, as they select the two-drum type for a twin boiler (Fig. 7). Because of the constantly increasing stoker and furnace loads it has become a common practice to surround the furnace with water walls which are included in the water circulation circuit of the boiler, and in some cases with superheater tubes. While boilers and water walls in America nearly always form two independent units, they are becoming in Germany more and more an organic whole, and it is often difficult to say which is the water wall and which the boiler heating surface (Figs. 6 and 8). Lately there have been offered two-drum boilers in which the same tube bank is forming the heating surface in the first and in the last passes (Figs. 3 and 4).

The boiler heating surface is being more and more replaced by economizer heating surface in which frequently a moderate steam generation is allowed (Fig. 5).

* Abstracted from a translation by H. R. Taube of a paper presented before the V.D.I. last summer and later amplified by the author and printed in pamphlet form, in German, by Julius Springer, Berlin. The present abstract is less than one-third the original text which includes an analytical study of the questions involved, performance and comparative costs, accompanied by 48 illustrations.

While American and English engineers prefer economizers consisting of straight tubes rolled into headers, the prevailing German preference, at least where condensate is used as feedwater, is for the considerably cheaper welded-tube elements. Due to the fact that feedwater preheated by bled steam in condensing power plants brings a considerable thermal gain, and in back-pressure power plants an increase in power, it is frequently brought up to a temperature of 200 deg, and, in consequence, the combustion air can be highly preheated by the gases leaving the economizers. If the flue gases have to heat besides an intermediate superheater, it becomes necessary to obtain in the primary superheater at full load a temperature of 1100 to 1250 deg F. A particularly cheap radiation boiler is the result, while the drums and downtake tubes required for convection heating surfaces are eliminated. There are, however, insufficient data available concerning superheaters exposed to such high gas temperatures.

SECTIONAL BOILERS. In the case of sectional boilers it is also possible to discern clearly a trend of development resulting logically from the expected performance (Figs. 9 and 10). An important feature is the installation of the superheater within the subdivided boiler heating surface (interdeck boilers) which originally used to include also an intermediate superheater. In more recent boilers the whole boiler heating surface has been reduced to only about eight tube rows arranged before the superheater. In Germany, sectional boilers for pressures of over 1000 lb per sq in. are not yet in operation.

It is easier to obtain reliable circulation in V-type boilers. In particular in interdeck sectional boilers the tubes following the superheater show a tendency to corrosion or to burning out, because the water they contain is stagnant. Sectional boilers with only one tube bank, consisting of a few rows of tubes arranged before the superheater and a large distance between upper drum and upper tube row, are safer. It is possible that our more thorough study of natural circulation explains the fact that we avoid conditions which might impair circulation, for instance, downtake tubes of sectional boilers exposed to heat. But now American practice is also beginning to show greater caution and is, for instance, increasing the distance between the upper drum and the upper boiler tube row, and also the number of risers between steam containing headers and the upper drum.

In V-type boilers it is advisable for high pressures not to use risers which are at their upper end exposed to comparatively high temperatures, expecially if they have great head, or contain occasionally water which is much colder than the content of the boiler.

Special steam collectors are of little value for obtaining dry steam. Extensive contact surfaces would probably be more effective for eliminating water carried away by the steam, than low velocities in large free spaces. High-pressure steam, independent of the boiler type used, shows a much greater tendency to carry away salts contained in the feedwater than steam under 600 lb, because at high pressure and temperature certain salts evaporate, and because, due to the considerably smaller difference in the specific weights of water and steam, more water containing salts is carried away by the steam. At any rate, high-pressure steam contains, even under the most favorable conditions, always several milligrams per liter of salt if chemically treated feedwater is being used. It seems that the washing of steam by the water fed into the boiler reduces the salt content of the steam considerably. An even better effect might possibly be obtained if the feedwater (or the condensate which is added to it) is, before entering the boiler, brought into close contact with the saturated steam in a special washing drum by means of mechanical stirring over large contact surfaces.

Separating drums arranged above the upper drum (*a* in Fig. 4) or intermediate drums (as *b* in Fig. 11) should be useful in case of chemically treated feedwater, because a boiler shows greater tendency for priming if the risers discharge into the upper drum large quantities of water mixed with steam, that is, with high velocity in numerous individual jets. For this reason water walls should be connected with the upper drum in such a way that the water-steam mixture generated in them undergoes, before entering the drum, a certain separation of water and steam (Fig. 11). The conditions are different if, as is the case in boilers with forced circulation, the steam-water mixture leaving the boiler tubes is being forced out by a special device.

To my belief the following measures are to be recommended, and they are the more important the higher the pressure, the more frequently and abruptly the changes in load and the more the chemically treated make-up water is being used:

1. If V-type boilers with two upper drums are used, to connect each of the drums with a heating surface of approximately the same size.
2. To connect risers and their corresponding downtakes of V-type boilers, if possible, with the same upper drum.
3. To keep separate, as much as possible, the water circulation circuits of the different water walls.
4. To arrange the most active risers in such a way that they discharge above the water level.
5. To distribute the risers of extensive water walls over the whole length of the upper drum and, if possible, to arrange them in such a way that water and steam separate before entering the upper drum.
6. To connect sectional headers containing steam by at least two risers with the upper drum with at least one riser discharging above the water level.
7. The quantity of steam generated per cubic foot of steam space should be in inverse ratio to the percentage of chemically treated water in the total quantity of feedwater, and to the amplitude of fluctuation of load.
8. To preheat the feedwater in the economizers up to nearly the temperature of saturated steam.

In conclusion one might say that modern German V-type boilers for high pressure are generally characterized by the following features: furnaces with water walls forming an organic whole with the boiler, the use of only two boiler drums connected with each other by downtakes not exposed to heat, small boiler convection heating surface, large tube coil economizers, highly preheated combustion air and high feedwater preheating by bled steam. As pulverized coal firing permits higher air temperatures than stokers, it is better suited for high-pressure boilers.

Principles and Advantages of Forced Circulation

There is a limit to the reduction of the cost of water-

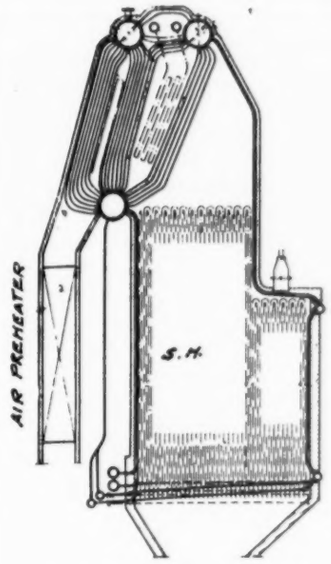


Fig. 1—Three-drum CE bent-tube boiler at Port Washington Station, designed for 1390-lb pressure and 690,000 lb of steam per hour

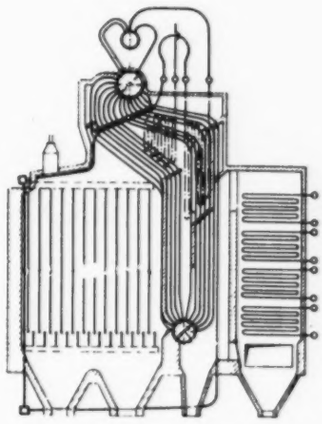


Fig. 2—Two-drum 1450-lb Handmag boiler of 140,000 lb per hr capacity in Mannheim Station

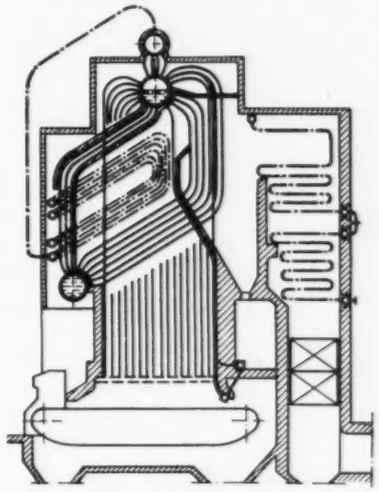


Fig. 3—Steinmüller two-drum, bent-tube boiler designed in 1933

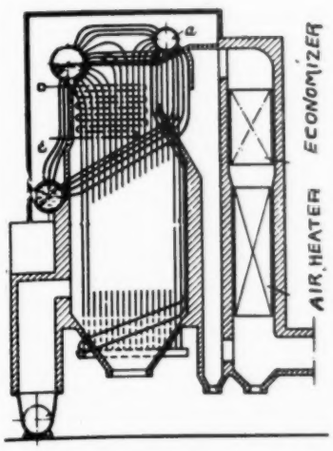


Fig. 4—A 1200-lb pressure, 90,000 lb per hr boiler designed in 1935 by the German B & W Co.

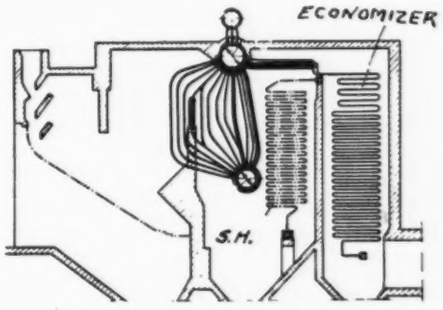


Fig. 5—Borzig two-drum boiler of 1935 designed for 80,000 lb per hr at 1760 lb per sq in. pressure

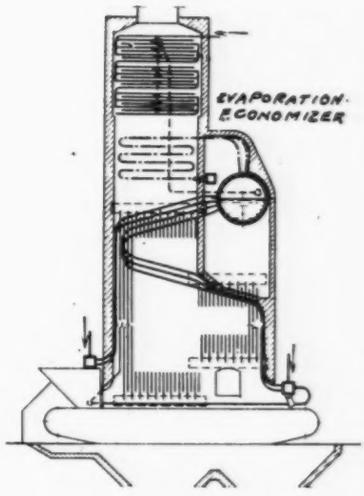


Fig. 6—Borzig single-drum boiler designed in 1933

tube boilers by reducing the number of drums and by extensive utilization of the flue gases in economizers and air preheaters. This is due to the conditions imposed by natural circulation requiring complicated riser and downtake tubes, and downtakes not exposed to heat. Moreover, the boiler remains comparatively rigid even in the case of bent-tube boilers, and the water circulation is frequently somewhat uncertain.

With forced circulation, when a pump is forcing the water through the heating surface, the restrictions with regard to diameter, length and arrangement of boiler tubes are much less exacting, and it becomes easier to design a flexible boiler heating surface and to adapt the boiler to given conditions (for instance limited height). As it is easy to design heating surfaces in the form of continuous coils made of tubes of not more than 60 mm (2.36 in.) inside diameter and as the riser and downtakes of the water walls with natural circulation become unnecessary, or can be simplified, the water walls cost scarcely more than the heating surfaces, properly speaking, and the resulting boiler is very flexible. Boilers with forced circulation are particularly well suited where short starting-up periods, high rates of heat liberation in the furnace, and high pressure are required. For pressures of over 150 lb they fill a need for boilers of up to about 10,000 lb per hr capacity, because they can usually be shipped completely assembled, and because normal water-tube boilers of such small capacity are less suited because of the required brickwork.

One speaks of forced circulation when the heat absorber (water in the La Mont and the Velox boilers and steam in the Loeffler boiler) is being continuously circulated through the heating surface by a pump, and of forced flow in boilers such as the Benson and Sulzer-one-

tube types[1] when as much water is forced over the heating surface, as has to be evaporated. While in boilers of this latter type the feed pump produces the forced flow, the La Mont, Velox and Loeffler boilers require special circulating pumps, which are not very desirable.

Performance of Boilers with Forced Circulation

An important difference between boilers with forced circulation and those with forced flow is that the former may be blown off, and the water level kept constant as in normal water-tube boilers, whereas, in the latter impurities in the feedwater, in so far as they are not deposited on the heating surface, get into the turbine; also special regulating devices are required to maintain constant ratios between fuel and air admission and steam consumption. For this reason forced flow boilers make much higher demands on the quality of the feedwater, than boilers with forced and natural circulation. In the Benson boilers an attempt has been made to overcome this weakness by subdividing the heating surface into several sections, each of which can be shut off from the rest. Those parts of the heating surface which are above or below the saturation temperature at which, as experience shows, salts are deposited, are placed in such low gas temperatures that salt encrusted tubes do not burn. Furthermore, the separate sections have from time to time to be washed out. It seems also that attempts are being made to remove the salt from the steam by throttling, whereby the salts are supposed to settle on planes placed behind the throttling device.

Sulzer introduces settling vessels between the point where nearly all water has evaporated and the superheater. To prevent collection of mud in the last part of the evaporator zone, a certain part of the feedwater, which is introduced in abundance, is continuously drained off.

Opinions concerning the permissible concentration in the drums of Loeffler boilers are still divided. Though these boilers can operate with water not any more suitable for forced flow boilers, they seem nevertheless to be less sensitive to impure feedwater than had been expected when they first appeared.

There are available very favorable reports about the La Mont elements and boilers concerning their lack of sensitiveness with regard to chemically treated feedwater. They seem to confirm the opinion that the formation of scale decreased with rising velocity of circulation.

Stopping of circulation and its eventual reversal do not occur in forced circulation boilers. The next step would be to increase the pressure of the circulating pump and to use the high velocity resulting herefrom for forcing the water-steam mixture into the boiler drum. The Velox boiler uses this feature deliberately by leading the water-steam mixture tangentially along the inner surface of a cylinder provided with numerous small holes.

It seems also that the Velox boiler shows comparatively little sensitiveness to impure feedwater, a fact which the Bevarian Boiler Insurance Society ascribes primarily to an explosion-like formation of steam bubbles at high ratings which prevent a formation of scale on the inner tube surfaces. The ample water velocity at all ratings has a similar effect.

Power Consumption of the Feed and Circulating Pumps

In boilers designed to operate with forced flow the feed pumps have to overcome a considerably higher pressure than in units with natural or forced circulation.[2] Boilers with forced circulation require special circulating pumps in addition to the feed pump. Because of their high steam consumption at low boiler pressure, the use of Loeffler boilers for pressures under 1500 lb per sq in. is not advisable. The relative power consumption of the feed and circulation pumps is the highest for Loeffler boilers, the lowest for boilers with natural circulation; for La Mont and Velox boilers and for boilers with forced flow it is a little higher than for the normal type water-tube boilers. In the case of hot feedwater, or in heating plants with high back-pressure on the turbine the additional power consumption of the feed and circulation pumps can become very noticeable. To reduce the steam consumption of the circulation pump, and in order to make the Loeffler boiler practicable for pressures from about 750 lb and up, efforts are now being made to send the steam from the circulating pump, after a first superheating through heating coils surrounded by the water which is to be evaporated, and then, after a second superheating, to blow it into the water content of the boiler drum. It is claimed that a further reduction of the steam consumption of the circulating pump can be obtained by discontinuing the use of working steam in the pumps. The considerable economy in steam and the extension of the economically advisable pressure limits is, however, partly compensated by the necessity of periodical cleaning of the heating coils, as is also the case in the Schmidt-Hartmann boiler.[3]

REGULATION. In La Mont, Velox and Loeffler boilers, as in boilers with natural circulation, a constant water level in the drum can be maintained either by hand or by means of an automatic level regulator. The drum acts as a shock-absorber and makes it unnecessary to adapt immediately or accurately the feedwater and fuel supply to changing loads. In La Mont and Velox boilers, in which the heating surface can never act as superheater surface, the temperature of the saturated steam produced will change not more than in boilers with natural circulation. In Loeffler boilers the steam temperature can be maintained constant by adjusting the circulating pump correspondingly. In boilers with forced flow, to the contrary, the zone between evaporating and superheating surface is shifting with fluctuating ratings. Automatic regulation in boilers with forced flow is therefore more difficult, because special means are required to adjust steam consumption, fuel, air and feedwater admission quickly and without undesirable change in the superheat temperature, to the changing load.

Because of the great inertia of boilers and furnaces, (especially if stoker fired) as compared with turbines, it

[1] The Sulzer single-tube boiler consists of a few identical tube elements, arranged in parallel, and separated from one another from the point of feedwater inlet to the outlet of the superheated steam, though sometimes several elements have settling vessels in common. In the Benson boiler numerous bundles of tubes, arranged in series are connected by means of headers. The tube diameter and numerous bundles are adapted to the variable specific volume of the heat absorber.

[2] In Sulzer single-tube boilers the pumping pressure for steam of 1500 lb and 850 F at full load is about 1900 lb, the pressure loss in the economizer section about 200 lb, in the evaporator section about 150 lb and in the superheater section about 90 lb. In the Benson boiler the conditions are probably similar. The pressure head of the circulating pumps in La Mont boilers is about 37 lb and in Loeffler boilers about 60 lb.

[3] The Schmidt-Hartmann boiler combines a steam generator and a steam regenerator in such a way that the flue gases are coming in contact exclusively with a heating surface filled with distilled water. This boiler is mainly intended for installations furnishing steam for heating purposes.

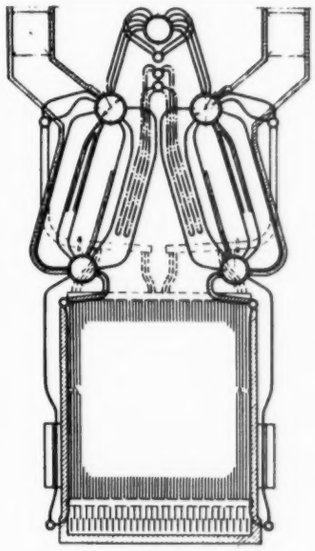


Fig. 7—Twin CE bent-tube boiler installed in Rouge Power Plant of Ford Motor Co. in 1931 to operate at 1400 lb

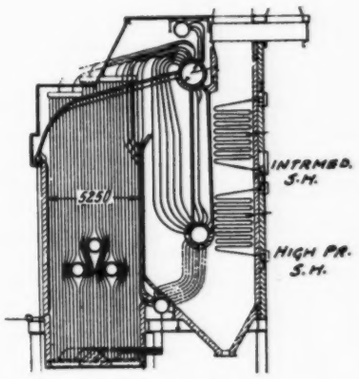


Fig. 8—Dürr bent-tube boiler, 1933, for 156,000 lb per hr at 1700-lb pressure

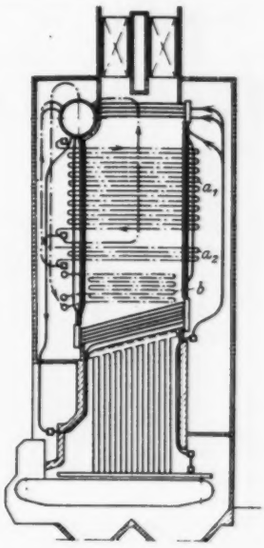


Fig. 9—Sectional-header design by German B & W, 1933, for 1900-lb pressure

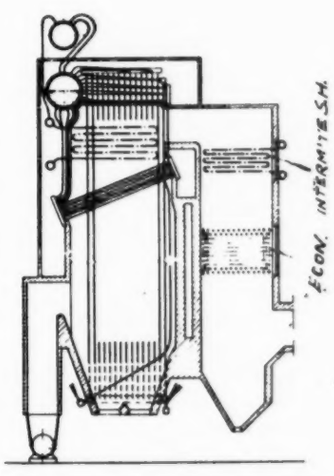


Fig. 10—Steinmüller sectional-header design, 1935, for 80,000 lb per hr at 1800-lb pressure

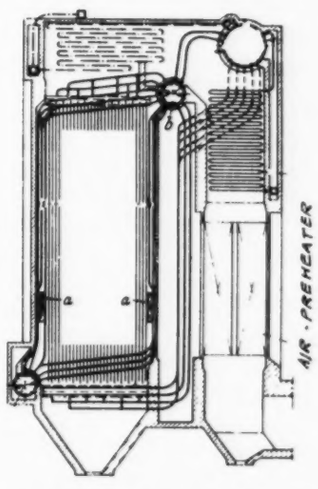


Fig. 11—470-lb pressure radiation boiler of 75,000 lb per hr capacity built in 1935 (Kohlenscheidungs-Gesellschaft)

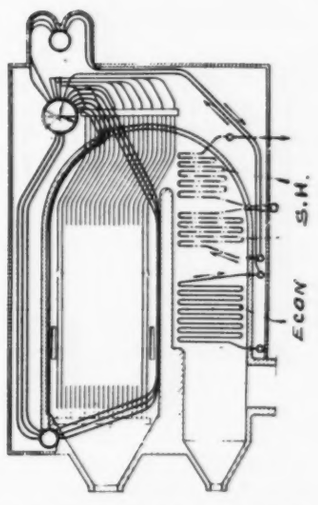
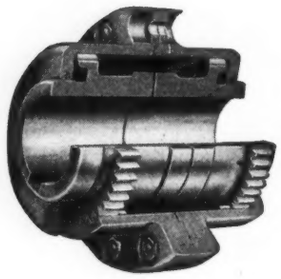


Fig. 12—Radiation boiler designed in 1935 by Dürrwerke for 90,000 lb per hr at 1760 lb per sq in.

is necessary in forced-flow boilers to derive the regulating motions required for changing loads from parts reacting more promptly, in order to make the regulation sensitive. The change of the most important factors of operation, feedwater and fuel supply, is today usually performed by devices under distant control, acting under the stimulus of superheater temperature, the steam flow, the electric load of the plant or the back pressure. As it requires several minutes before a water particle has traveled over the whole heating surface, the effect of a thermostat placed at the superheater outlet would be too slow. But near the beginning of the boiler heating surface the change of temperature takes place at about the same ratio as at the superheater outlet, while it adapts itself much quicker to the new condition.

For this reason Sulzer uses two thermostats with hydraulic transmission for fluctuating ratings. The thermostat serving for fine adjustments is situated after the superheater and produces an injection of water into the superheater. The intermediate thermostat is installed immediately before the point of injection, and acts upon the feedwater and fuel admissions. A further improvement of the adjustment is effected by a differential regulator and intermediate thermostat. This regulator acts under the influence of the frequency of temperature changes which gives a useful measure of the amplitude of fluctuation of ratings. By means of a so-called addition slide, it is possible to obtain action from the sum of the absolute values of temperature and of the velocity of its change. Moreover, an automatic overflow valve maintains the pressure constant behind the superheater, which prevents the priming of the boilers at high peak loads. If the steam consumption drops to less than 25 per cent of full load, another automatic valve lets the

Specifying



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steam enter the condenser or leads it to the points of utilization of low-pressure steam.

In the Benson boiler the capacity is regulated by a main regulator, which shifts the established ratio of fuel, air and feedwater. At the same time a regulator activated by a distance thermometer, installed either in the boiler heating surface or near the superheater outlet, maintains a constant superheat temperature. The pressure in the furnace is influenced by a special pressure regulator.

Sulzer avoids, as a rule, regulation by hand for oil- or gas-fired furnaces, but in the Benson boiler regulation for hand operation takes place at the superheater outlet by means of a push-button in accordance with the readings of a distance-thermometer. It will in many cases prove advisable to adjust fuel, water and air admission roughly by hand and to leave the fine adjustment to special regulators. For the regulation of stokers automatic devices are seldom used. In La Mont boilers it is possible to make the boiler drum sufficiently large to smooth out even the greatest unexpected changes of load, whereas in forced flow boilers special shock-absorbers are probably necessary. In plants where steam is used for heating or process purposes they can usually be provided in the form of accumulators at some suitable point of the low-pressure piping system. This is not the case in condensing power plants where one must be satisfied to have the load changes absorbed by boilers with natural circulation and ample water content. But even in the case of oil- and gas-fired boilers it is doubtful if automatic regulation of forced-flow boilers can be made sensitive enough for purposes of electric power generation. The view prevails today that with forced-flow boilers, the boilers and turbines must be regarded as a unit from the point of view of their regulation. While the Benson boiler is able, in the case of sharply changing loads, to furnish, due to drop of pressure, a certain additional quantity of steam, this is impossible in the Sulzer boiler which is regulated for constant saturated steam pressure.

In forced-circulation boilers it is, after all, possible to make the drum of sufficient size, even at very high pressures, to bridge periods of feed interruption lasting 5 to 10 minutes, an advantage brought by the necessity of having to install special circulating pumps.

In starting up of forced-flow boilers it is necessary to create first an artificial flow; for starting up Loeffler boilers auxiliary steam from another boiler is required, whereas La Mont boilers and boilers with natural circulation do not require any special measures.

Boilers with forced circulation are, to my belief, primarily suited for the following four purposes:

1. As small boilers for capacities of up to 10,000 lb per hr for nearly all kinds of fuel. They are especially useful for the export trade when suitable feedwater or expert water treatment is available; for the German boiler industry they offer good promises if industry makes use of the favorable position it is holding today, and if it takes in consideration the special conditions in the export countries.

2. For medium and high pressures for all capacities.

3. For special purposes, such as peak-load and reserve power plants.

4. For oil-firing (especially for export) and for gas firing (especially for the steel industry) for all capacities.

Action of Solutions of Sodium Silicate and Sodium Hydroxide at 250 C on Steel under Stress*

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Reference was made editorially in the January issue to the discovery that the presence of sodium silicate in sodium hydroxide solutions is responsible for so-called caustic embrittlement. The present paper which was prepared for presentation at the February meeting of the A.I.M.M.E. and also printed in "Metals Technology" for January, gives an account of the investigations that led to this discovery. The introduction has been rewritten by the authors for COMBUSTION.

FOR a number of years it has been believed that sodium hydroxide was the only chemical which was primarily involved in the embrittlement of boiler steel. The work of various investigators was not, however, in complete agreement and in 1934 (1)[1] strong evidence was advanced to show that chemically pure sodium hydroxide would not produce a measurable decrease in the pure tensile load which a steel specimen would sustain. On the basis of some investigation which was carried out at the U. S. Bureau of Mines during the summer of 1935 it was discovered that the introduction of a small amount of sodium silicate into the sodium hydroxide solutions produced a sharp reduction in the load which a steel specimen would carry. These results were reported to a sub-committee of the A.S.M.E. Joint Research Committee on Boiler Feedwater Studies[2] on October 1, 1935.

The effect of these sodium silicate-sodium hydroxide solutions has since been at least partially confirmed by the work of F. G. Straub and T. A. Bradbury (2), and the work of A. S. Perry (3). In Perry's work it was not stated that the sodium hydroxide which was used for the tests contained sodium silicate, but an analysis of a sample of this material at the Bureau of Mines showed that this was the case.

Although the investigation is still in its early stages, sodium silicate has been found to play such a totally unexpected part in the embrittlement phenomenon that it seems highly desirable to indicate at the present time the progress of the research. A brief description of the testing equipment will be followed by a discussion of the tests with concentric-ground specimens, the tests with eccentric-grooved specimens and the conclusions drawn from these tests.

Equipment

The essential procedure followed in the investigation consisted in stressing steel specimens in a small bomb or autoclave while they were in contact with water or aqueous solutions at an elevated temperature. The distinction between rapid failure in some cases, and no failure, over periods up to 43 days in others, supplemented by microscopic examination of the fractures obtained, has been used to measure the effect of solution composition.

The bomb, the lever system by which the load was applied and the jacket which acted as an air thermostat are shown in Fig. 1. The temperature of the bomb was controlled by a bimetallic element in the air space between the electrically heated jacket and the bomb. An electric clock, controlled by a switch under the lever arm, indicated the time of failure for the specimen being tested. The lever system was accurately machined and located and was checked against a Southwark-Emery hydraulic testing machine. The calculated value for the load (lever arm ratio times weight added on lever) was found to be within two per cent of the value indicated by the testing machine throughout the entire load range.

It will be noticed that the test piece consisted of a tubular specimen closed at one end and that the load was applied by means of a rod passing through the center. This specimen eliminated the necessity for a packing gland, thus obviating both leakage and the possibility that the gland might exert sufficient friction to cause a serious error in the load actually applied to the test piece. The fact that the tubular specimen, as compared to a solid one, had a higher ratio of surface exposed to solution to cross-sectional area of metal was also considered to be an advantage.

The two types of test specimen used are shown in Fig. 2. The one indicated as concentric ground was carefully prepared to insure a uniformly distributed tensile load, with a minimum of bending. The reduced section was ground with a fine emery wheel running parallel to the length to eliminate surface scratches perpendicular to the direction of application of the load.

In the grooved specimens the outer and inner cylindri-

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[1] Numbers in parenthesis refer to references at end of article.

[2] Sponsored by the American Boiler Manufacturers' Association, the American Railway Engineering Association, the American Society of Mechanical Engineers, the American Society for Testing Materials, the American Water Workers Association and the Edison Electric Institute.

cal surfaces were concentric but the groove was cut on an axis displaced 0.010 in. from the axis of these surfaces. The radius at the base of the groove was 0.0056 in.

The test pieces were machined from a one-inch plate of boiler flange steel prepared by the Carnegie Steel Company. The physical properties of the steel in the region from which the test specimens were taken are shown in Table I and the chemical analysis in Table II.

All of the tests described in this paper were conducted at 250 C corresponding to a gage pressure for water of 38 atmospheres (482 F, 561 lb per sq in.).

Two series of tests were carried out with concentrically ground specimens; the first to compare the action of pure sodium hydroxide solutions with the action of water, and the second to determine the specific effect of added sodium silicate.

Effect of Water and Sodium Hydroxide Solutions on Concentric-Ground Specimens

The results in Table III indicate that the ground specimens required a tensile load of about 82,500 lb per sq in. to produce failure in short-time tests under progressively increasing load. These tests were conducted by placing the test piece and solution into the bombs, bringing the temperature to 250 C., and then slowly adding weights to the end of the lever arm until failure occurred. The steel was under load about two hours. The fact that the tensile strength indicated in this table is higher than shown for the standard solid specimens at 250 C in Table I may be attributed to the differences in shape of the specimen and rate of loading. These results were checked in an oil bath in the tensile strength testing machine and good agreement was obtained.

It should be noted in Table III that contact with a concentration of sodium hydroxide of 25 grams per 100 grams of water did not lower the short-time breaking strength as compared to the value obtained in water.

The results in Table IV show that three specimens in water and sodium hydroxide solutions subjected to a steady load of 75,000 lb per sq in. did not fail in periods up to 43 days. Comparison of Tables III and IV indicates this average applied stress is within 7500 lb per sq in. of the load required for failure. From these results it can only be concluded that contact with a solution of sodium hydroxide, under the conditions and concentrations indicated, does not produce any marked effect on the tensile load which the steel can sustain.

These results are at complete variance with those reported by Straub (4) in Bulletin 216 of the University of Illinois Engineering Experiment Station, who found that tensile loads slightly above the room-temperature yield point would cause failure when the steel was in contact with approximately this concentration of sodium hydroxide at 500-lb gage pressure. Ulrich (5) in Germany found, however, that steel under these conditions would carry for long periods a tensile load more than 50 per cent higher than the room temperature yield point. Two investigations conducted in the United States during the period from 1932 to 1935 (6)[3] also indicated that sodium hydroxide in concentrations up to 50 grams per 100 grams of water did not produce a measurable effect on the ability of steel specimens to carry a tensile load.

[3] Private communication.

Effect of Solutions of Sodium Silicate and Sodium Hydroxide on the Concentric-Ground Specimens

In the first attempt to explain these differences, samples of steel were exchanged with Professor Straub but the respective results were unaffected. Professor Straub later[4] advised the authors that in two tests with chemically pure sodium hydroxide he had been unable to produce failure of his specimens under conditions which previously had resulted in rapid failure when he used commercial sodium hydroxide. The latter grade of material had been used by him in most of the tests reported.

Professor Straub kindly provided the authors with some of this material. The results of a series of tests with it on concentric-ground specimens are shown in Table V. Failure occurred in a few hours at loads as low as 55,000 lb per sq in., where no failure had previously been obtained with chemically pure sodium hydroxide in 43 days under a load of 75,000 lb per sq in. It will be noticed in Table V that some of the specimens failed at

TABLE I

AVERAGE PHYSICAL PROPERTIES OF THE BOILER FLANGE STEEL AT ROOM TEMPERATURE AND 250 C.

Temperature	Lb per Sq In.		Per cent	
	Yield Point	Tensile Strength	Elong.	Red. area
Room	28,000	58,000	40	63
250 C	21,000	69,000	33	53

Tests carried out on Standard A.S.T.M. specimens.

TABLE II

CHEMICAL ANALYSIS OF THE BOILER FLANGE STEEL

Constituent	Per cent
Carbon	0.17
Manganese	0.47
Phosphorus	0.021
Sulphur	0.039

Ladle analysis supplied by manufacturer.

TABLE III

SHORT-TIME TESTS IN THE EMBRITTLEMENT BOMBS TO DETERMINE THE BREAKING LOAD FOR CONCENTRICALLY GROUND SPECIMENS

Temperature 250 C.

NaOH Concentration, g/100 g H_2O	Breaking Load, Lb per Sq In.
water	82,700
	82,100
25	83,300
	82,100
Average	82,550

TABLE IV

RESISTANCE TO FAILURE OF CONCENTRICALLY GROUND SPECIMENS IN WATER AND SODIUM HYDROXIDE

Temperature 250 C

NaOH Concentration, g/100 g H O	Average Applied Stress, Lb/Sq In.	Duration of Test, Days
water	75,000	43
25	75,000	21
25	75,000	43

TABLE V

FAILURE OF CONCENTRIC-GROUND SPECIMENS IN COMMERCIAL SODIUM HYDROXIDE

25 Grams of NaOH per 100 Grams of Water

Temperature 250 C.

Average Applied Stress, Lb per Sq In.	Failure, Hours	No Failure, Days
70,000	12	
70,000	55	
70,000	17	
65,000	32	
65,000	29	
60,000*	58	
55,000*	56	
50,000		10

* Failure at shoulder.

[4] Private communication.

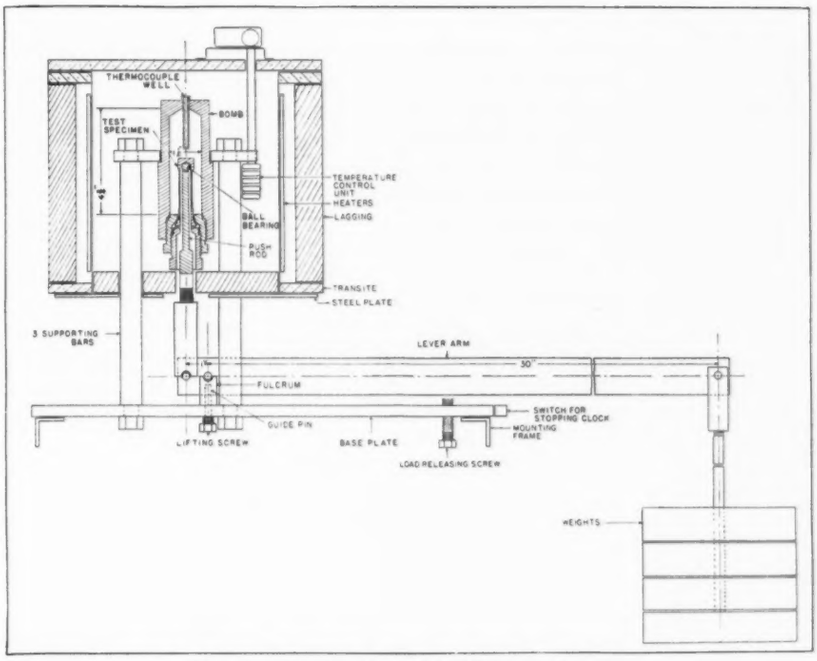


Fig. 1—Test bomb and loading mechanism

the radius near the top or bottom instead of the ground section in the middle. This probably resulted from a slight concentration of stress at these radii but since microscopic examination of such specimens indicated that the ground section was also cracked in almost every case, this is not believed to be important.

From the results shown in Table V it may be concluded that either the commercial sodium hydroxide contained some impurity which caused or perhaps catalyzed the reaction to produce failure, or the chemically pure solution contained some substance which inhibited the reaction. The weight of evidence was toward the first view and subsequent results prove that this was correct.

An analysis of the commercial sodium hydroxide is given in Table VI. A quantitative determination was performed for all components present in appreciable concentration and a qualitative analysis was made for a number of other components. Quantitative analysis of the chemically pure sodium hydroxide, which was stored as a saturated solution in a paraffined bottle, indicated 0.2 per cent sodium carbonate and 0.02 per cent sodium silicate. These values are approximately $^1/_{10}$ and $^1/_{30}$ of the amounts of the same compounds found in the commercial sodium hydroxide. The chemically pure material contained negligible quantities of sodium chloride and R_2O_3.

With these analyses as a guide, the salts present in the commercial sodium hydroxide were added to solutions of the chemically pure substance, with the results recorded in Table VII. It is seen that only those solutions which contained sodium silicate caused failure. In the last sample when sodium silicate alone was added to the sodium hydroxide solution failure also resulted.

The data in Table VIII indicate the effect of varying the silica concentrations on the failure of the specimens. With concentrations much below 0.15 grams per 100 grams of water and 25 grams of NaOH per 100 grams of water, failure was not encountered in periods up to 10 days. As the silica concentration was increased, the time for failure tended to become somewhat shorter, but at 10 grams per 100 grams of water this effect was apparently reversed. Too much reliance cannot, however, be placed on small differences in the time required for failure, as this value is doubtless affected by a number of rather uncontrollable factors.

TABLE VI

ANALYSIS OF COMMERCIAL SODIUM HYDROXIDE

Quantitative Analysis

Component	Per cent
NaOH	95.9(*1*)
Na_2CO_3	2.10(*2*)
NaCl	0.57
Na_2SiO_3	0.64
R_2O_3(Al_2O_3 (Fe_2O_3)	0.05
Ca	trace

Qualitative Analysis

Component		
Heavy metals	(Pb-Hg, etc.)	none
Arsenic		none
Sulphides		none
Magnesium		none
Peroxide		trace
Cyanides		none
Sulphates		trace

(*1*) Not corrected for R_2O_3 or Na_2SiO_3
(*2*) Determined by evolution.

TABLE VII

FAILURE OF CONCENTRIC-GROUND SPECIMENS IN SOLUTIONS CONTAINING SODIUM SILICATE AND SODIUM HYDROXIDE

Temperature 250 C.

Average Applied Stress, NaOH Concentration		70,000 Lb per Sq In., 25 g per 100 g H_2O	
Added Salts	g/100 g H_2O	Failure, Hours	No Failure, Days
Na_2CO_3	0.5	..	4
NaCl	0.13		
Na_2CO_3	0.5	..	
NaCl	0.13	..	6
Na_2CO_3	0.5		
NaCl	0.13	..	7
(*1*) Al_2O_3	0.05		
Na_2CO_3	0.5	34*	
NaCl	0.13		
(*1*) Al_2O_3	0.05		
(*2*) Na_2SiO_3	0.2		
Na_2CO_3	0.5	21	
NaCl	0.13		
(*2*) Na_2SiO_3	0.2		
(*2*) Na_2SiO_3	1.5	77	

(*1*) Added as aluminium chloride.
(*2*) Baker's water glass 40% solution, used to introduce silica into bombs.
* Failure at shoulder.

Table VIII also shows that failure can be secured at loads as low as 55,000 lb per sq in. The fact that the one sample which failed at this load also contained sodium carbonate and sodium chloride does not necessarily indicate that these salts exert an appreciable effect on the results, since this stress is apparently near the border line for failure or no failure.

It will be noticed from Tables VII and VIII that the sodium silicate could be introduced into the bombs either from a solution of water glass or from chemically pure $Na_2SiO_3.9H_2O$ dissolved in water without producing any apparent differences in the results.

A large number of microscopic examinations have been made of specimens broken in sodium hydroxide solutions and in sodium silicate-sodium hydroxide solu-

TABLE VIII

EFFECT OF STRESS AND SODIUM SILICATE CONCENTRATIONS ON THE FAILURE OF CONCENTRIC-GROUND SPECIMENS

25 g NaOH per 100 g H_2O		Temperature 250 C.	
Average Applied Stress, Lb per Sq In.	Na_2SiO_3 g per 100 g H_2O	Failure, Hours	No Failure, Days
70,000	0.077	..	10
70,000*	0.15	32	..
70,000	0.40	44	..
70,000	1.7	10	..
70,000	5.0	8	..
70,000	10.0	135	..
70,000	10.0	80	..
60,000*	3.0	135	..
60,000	3.0	120	..
55,000	0.16	..	10
55,000*	0.16 (*1*)	152	..

* Failure at shoulder.
(*1*) Solution also contained 0.52 g Na_2CO_3 and 0.11 g NaCl per 100 g H_2O.

TABLE IX

SHORT-TIME TESTS IN THE EMBRITTLEMENT BOMBS TO DETERMINE THE BREAKING LOAD FOR ECCENTRIC-GROOVED SPECIMENS AND THE LOAD WHICH THEY WILL CARRY IN WATER ALONE

All specimens in Water	Temperature 250 C.
Average Applied Stress, Lb per Sq In. (*1*)	No Failure, Days
73,500	Breaking test
70,200	Breaking test
70,000	Breaking test
65,000	15
65,000	15

(*1*) Calculated for area of metal at base of groove.

tions. One of the chief characteristics of the action of the silicate hydroxide solutions is the production of a very large number of almost completely intercrystalline cracks in the steel.

From these results it seems entirely safe to conclude that sodium-silicate sodium hydroxide solutions produce an effect on steel in tension entirely different than or greatly accelerated beyond that produced by sodium hydroxide alone.

Tests with Eccentric-Grooved Specimens

In practice, embrittlement is found to occur most frequently in regions where the steel can suffer a local stress concentration, for example under the head of a rivet, or around a rivet hole where it is likely that the stress will not be pure tension but tension combined with bending. Similarly, in the tests recorded in Tables V, VII and VIII a total of six specimens failed, not in the region of high, uniformly distributed stress, but in the region of non-uniform stress of unknown magnitudes, at the shoulders of the test pieces. The eccentric-grooved specimen was intended to produce similar conditions of stress concentration with a test piece which was as reproducible as possible. The results, as will be seen, indicate that both pure sodium hydroxide solutions, and sodium silicate-sodium hydroxide solutions have a much more pronounced effect on this specimen with localized stress than on the concentric-ground specimen with more uniform stress distribution.

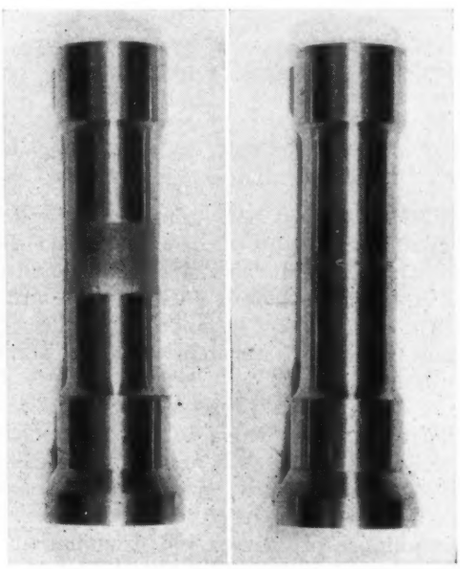


Fig. 2—Tubular specimens used in embrittlement testing

The first three values in Table IX give the load required in short-time tests to break the specimen in water in the bombs. The load was progressively increased in these tests during periods varying from about 15 to 30 min. The last two results in the Table show that the eccentric-grooved specimen will sustain a tensile load of 65,000 lb per sq in. in water for at least 15 days.

Table X shows that the stock solution of sodium hydroxide which contained only 0.02 per cent Na_2SiO_3 markedly reduced the load which could be sustained, failure occurring at loads as low as 50,000 lb per sq in. There was some tendency for the time of failure to increase as the load decreased but this was not regular or marked.

From these results it is not apparent whether the sodium hydroxide alone was responsible for the lower load which could be carried or whether this effect arose from the 0.02 per cent Na_2SiO_3 present. It is hoped to determine this before the investigation is concluded.

TABLE X

FAILURE OF ECCENTRIC-GROOVED SPECIMENS IN SOLUTIONS OF CHEMICALLY PURE SODIUM HYDROXIDE (*1*)

25 g NaOH per 100 g H_2O	Temperature 250 C	
Average Applied Stress, Lb per Sq In. (*3*)	Failure, Hours	No Failure, Days
67,400	13	..
68,600	4	..
65,000	8	..
65,000	6	..
62,000	18	..
62,000	80 (*2*)	..
59,000	6	..
59,000	19	..
55,000	37	..
55,000	36	..
50,000	21	..
50,000	..	12
45,000	..	10

(*1*) Na_2SiO_3 present is 0.02 per cent of NaOH concentration.
(*2*) Specimen stopped and reloaded after 50 hr.
(*3*) Calculated for area of metal at base of groove.

TABLE XI

FAILURE OF ECCENTRIC-GROOVED SPECIMENS IN SOLUTIONS OF SODIUM SILICATE AND SODIUM HYDROXIDE

25 g NaOH per 100 g H_2O		Temperature 250 C	
Average Applied Stress, Lb per Sq In (*3*)	Na_2SiO_3 g per 100 g H_2O	Failure, Hours	No Failure, Days
40,000	1.6	73	..
40,000	0.40	40	..
40,000	0.16	21	..
35,000	0.16	33	..
30,000	0.16 (*1*)	60	..
30,000	0.16	93	..
25,000	0.16 (*1*)	72	..
25,000	0.16	..	10 (*2*)
25,000	0.40	190	..
20,000	0.16 (*1*)	75	..
20,000	0.32	78	..

(*1*) Commercial sodium hydroxide referred to in Table VI.
(*2*) Microscopic examination showed embrittlement cracks.
(*3*) Calculated for area of metal at base of groove.

TABLE XII

FAILURE OF ECCENTRIC-GROOVED SPECIMENS IN MIXTURES OF PURE QUARTZ AND SODIUM HYDROXIDE

25 g NaOH per 100 g H_2O		Temperature 250 C.
Average Applied Stress, Lb per Sq In.	Na_2SiO_3 g per 100 g H_2O	Failure, Hours
40,000	0.46	43 (*1*)
30,000	0.30	21 (*2*)

(*1*) 99.4% pure SiO_2. Furnished by Eimer and Amend.
(*2*) Brazilian quartz. Furnished by Foote Mineral Co. of Philadelphia.

Table XI shows the effect of additions of sodium silicate to these sodium hydroxide solutions. Failure was produced at loads as low as 20,000 lb per sq in. This is a striking example of the effect of these silicate hydroxide solutions. This specimen which has a breaking load of approximately 70,000 lb per sq in. in water, will not even sustain a load of 20,000 lb when in contact with the solution containing both sodium hydroxide and sodium silicate. Three tests are included in this table to indicate the effect of the commercial sodium hydroxide which contained 0.64 per cent sodium silicate.

From the results with the concentric-ground test pieces in Tables VII and VIII, it will be remembered that both water glass and cp sodium silicate ($Na_2SiO_3 \cdot 9H_2O$) had about the same effect in producing failure. The two results in Table XII were collected to eliminate the possibility of the introduction of any impurity with the sodium silicate. Samples of pure quartz were secured from two different sources, fused with the cp sodium hydroxide in nickel crucibles, dissolved in water and this solution was then used to introduce the silica in the bombs. Failure occurred in approximately the same time as for the silicate solutions previously employed, so that it seems safe to conclude that the latter contained no impurities which produced any marked effect in the reactions.

Table XIII shows the effect of solutions containing less than 25 grams of sodium hydroxide per 100 grams of water on the failure of the specimens. The first two tests with the cp sodium hydroxide which contained only 0.002 gram of sodium silicate per 100 grams of water, show that the specimens would not fail at a load of 65,000 lb per sq in. With the same concentration of sodium hydroxide and the additions of sodium silicate failure occurred in a few hours at 60,000 lb per sq in. At 7.5 grams of sodium hydroxide in the presence of sodium silicate failure occurred in two cases but with 5 grams of sodium hydroxide failure was not encountered in 3 tests. These results which are rather preliminary would indicate that 7.5 grams of sodium hydroxide is about the lowest concentration which will produce a measurable effect on the eccentric-grooved specimen at these concentrations of sodium silicate.

At the lowest concentration of sodium hydroxide the formation of a smooth adherent scale, which appeared to be an iron silicate, may account for the fact that no failure was secured. This silicate scale may have been sufficient to protect the steel from reaction with the solution.

TABLE XIII

EFFECT OF THE SODIUM HYDROXIDE CONCENTRATION ON THE FAILURE OF ECCENTRIC-GROOVED SPECIMENS

Average Applied Stress, Lb per Sq In.	g per 100 g H_2O Cone, NaOH	Cone, Na_2SiO_3	Failure, Hours	No Failure, Days
65,000	10	...	..	12
65,000	10	...	..	12
60,000	10	0.75	54	..
60,000	10	0.30	50	..
60,000	7.5	0.75	..	14
60,000	7.5	0.30	166	..
60,000	7.5	0.15	120	..
60,000	5.0	1.9*	..	10
60,000	5.0	0.75*	..	10
60,000	5.0	0.30	..	10

* Specimens, on removal from the bomb, were found to be covered with a very tightly adhering scale.

Conclusions

The following conclusions may be drawn from the data which have been presented.

1. At 250 C sodium hydroxide concentrations up to 25 or 50 grams per 100 grams of water do not produce any significant effect on the tensile load which steel specimens will sustain.
2. Additions of small amounts of sodium silicate to the sodium hydroxide greatly reduce the tensile load which can be carried.
3. On specimens subject to both tension and bending with a line of stress concentration it was found that the load which could be carried at 250 C was reduced from 65,000 lb per sq in. in water to less than 20,000 lb per sq in. in sodium hydroxide-sodium silicate solutions.
4. Microscopic examination of the specimens which failed in the sodium hydroxide-sodium silicate solutions has indicated that one of the characteristic effects of the presence of the silicate was the production of a large number of fine, intercrystalline cracks in the metal near the fracture.

The failure to recognize the part which sodium silicate played in the embrittlement of steel, and the use of sodium hydroxide solutions which contained from very little to relatively large amounts of sodium silicate, has resulted in a great deal of conflicting data regarding this type of failure. With this discovery at the U. S. Bureau of Mines of the action of the silica it is now possible to correlate many of these data.

Up to the present time no explanation backed by adequate experimental evidence has been advanced for the reactions which produce embrittlement. Considerable evidence is available to show that the hydrogen released by the action of the solutions on the steel is a very important factor. It is difficult, however, to see the exact part played by the silica in such a process. It is hoped to be able to determine the mechanism of the reactions during further investigations.

Acknowledgments

The authors wish to thank the many companies and individuals who have contributed to the support of this investigation and to acknowledge the constant guidance of J. H. Walker, Chairman of the sub-committee of the Joint Research Committee for Boiler Feed-Water Studies sponsoring this investigation and of Everett P. Partridge, formerly supervising engineer of this station of the Bureau of Mines, who have contributed greatly to the progress of this research.

References

(1) Schroeder, W. C. and Partridge, E. P. Effect of Solution Composition on the Failure of Highly Stressed Boiler Steel. Presented to A.S.M.E., Boiler Feedwater Session, December 1934.
(2) Straub, F. G. and Bradbury, T. A. New Laboratory Data Relative to Embrittlement in Steam Boilers. Presented to A.S.M.E., Boiler Feedwater Session, December 1935.
(3) Perry, A. S., Study of Effect of Concentrated Sodium Hydroxide on Boiler Steel under Tension. Presented to A.S.M.E., Boiler Feedwater Session, December 1935.
(4) Straub, F. G., Univ. Ill. Eng. Expt. Sta. Bull., 216, 128 pp. (1930).
(5) Ulrich, M., Vereinigung der Grosskesselbesitzer. Mitt. 25.
(6) Wagner, G. H. and Wall, J. R. Embrittlement of Boiler Steel by Caustic Soda. Presented to A.S.M.E., Boiler Feedwater Session, December 1935.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Chain Drive Selector

An ingeniously arranged sliding cardboard chart has been issued by the Morse Chain Company to facilitate rapid selection of a silent chain drive within the range of ½ to 150 hp. It selects the number of teeth in the sprockets, the pitch and width of the chain, gives the standard center distance, figures the chain length, the diameters of the sprockets and even indicates the sizes that are carried in stock. The selector is well put together and plainly printed on letter-size stock.

Erosion Prevention

A 12-page booklet just issued by The Debevoise Company discusses the prevention of erosion due to an impingement such as occurs at the inlet end of condenser tubes and pump impellers. For this purpose the company has developed an erosion-resistant coating, known as "Debecote." Quotations are given from the report of the A.S.M.E. Sub-Committee on Condenser Tube Corrosion to substantiate the effectiveness of this coating. Other power plant uses listed are hot-water tanks, pump linings, ash aprons for stokers, steam jets and fittings.

Gaskets

The Goetze Gasket & Packing Company has published a 64-page catalog illustrating and describing the numerous types of gaskets which it manufactures. For each type there are tables containing the price list and gasket dimensions for different pipe sizes, pressures from 125 to 600 lb and different types of flanges.

Heavy-duty Compressors

A new bulletin describing their line of power-driven, horizontal duplex, double-acting, cross-head type, moderate speed, heavy-duty compressors has just been issued by Ingersoll-Rand. The capacities covered range from 50 to 250 hp for single or multi-stage compression.

The types covered are the "XRE," which are direct-connected, synchronous motor-driven units; and the "XRB" and "XCB," which are belt driven.

All types are equipped with the new I-R Channel Valve.

Instruments and Control

Hays boiler instruments, Carrick combustion control and Cochrane flow meters, pressure gages and temperature recorders are grouped in a new publication No. 2246 showing boiler panels complete with every instrument necessary for accurate records, instantaneous information and centralized control. The object behind this combined service is to provide the customer with a unified and harmonized design that will completely fill his needs.

Lubrication Guides

The Standard Oil Company of Indiana has published a number of monographs on particular applications of lubricants. Those available are: Steam Turbine Lubrication, Diesel Cylinder Lubrication, Diesel Engine Bearing Lubrication, Steam Engine Lubrication, Lubrication of Coal Handling Equipment, Diesel Air Compressor Lubrication and the Lubrication Engineer—His Value to You.

Roller Bearings

A 12-page booklet issued by Link-Belt Company, Chicago, contains list prices, dimensions and weights of the several components of its "Series 400" line of anti-friction bearing units equipped with Shafer double-row roller bearings. Self-alignment in these bearings is provided by concave rollers between convex outer races and a spherical inner race on the sleeve, which is free to deflect with a shaft temporarily misaligned or out of line because of inaccuracies of installation. In addition to the tabular data information is given on selection, capacity shaft tolerances and lubrication.

Sectional-Header Boiler

Combustion Engineering Company has just issued a 16-page catalog illustrating and describing details of its sectional-header type boiler as built for a wide range of steam pressures, capacities and different methods of fuel firing.

In addition to the details of design, cross-sections of numerous representative installations are included, as well as shop photographs showing the fabrication of such boilers and their inspection. In these boilers fusion welding is standard and riveted construction optional.

Smoke Recorder

An illustrated 16-page catalog recently issued by Leeds & Northrup Company, describes the Micromax Smoke Density Recorder. By means of this instrument the man on the firing aisle can now have constantly before him a large dial on which a moving arrow indicates the smoke density. Management officials can have a continuous red ink record of actual performance. The recorder can automatically actuate signals, if desired, and additional recording instruments may be located at any point in the plant, regardless of distance from the stack. The principle upon which this instrument operates is as follows:

Two streams of stack gas are continuously drawn through widely separated inlets by an aspirator and merged in a sampling chamber. Through the entire length of this moving sample, radiation passes from an electric lamp at one end to a thermopile at the other. This radiation, falling on the thermopile in inverse proportion to the density of the smoke sample through which it passes, generates an electromotive force which is measured by the recorder.

Speed Control

A 109-page speed-control handbook has lately been issued by the Reeves Pulley Company of Columbus, Indiana. The book is replete with data on industrial speed control and shows how Reeves variable-speed transmission is applied in various uses.

Steam Distribution Equipment

The American District Steam Company is distributing upon request, a new loose leaf, illustrated catalog No. 35 with over 130 pages of engineering, dimensional and price data on the complete ADSCO line of expansion joints, meters, steam traps, pipe casing, water heaters, vapor heating specialties, pipe fittings and other steam distribution equipment.

This catalog includes descriptive bulletins on the new ADSCO packless expansion joint, the piston-ring and duplex-sleeve slip-type expansion joints as well as the several other types of expansion joints. It covers also new vertical steam traps, rotary condensation meters, steam-flow meters, instantaneous and storage water heaters, wood casing, pipe fittings, vapor heating specialties and other steam-distribution equipment.

Tube Cleaners

A catalog has been issued by the Roto Company, manufacturers of tube cleaners which consists of two sections bound in a single cover—a "Tube Cleaner Manual," and a loose-leaf section describing the company's line.

The manual illustrates with photographs and blue prints, various problems of mechanical tube cleaning and their solution. Various types of tube cleaners are analyzed so as to assist the prospective purchaser in selecting the type best suited for his specific requirement.

Besides tracing and illustrating the history of tube cleaners, the manual briefly covers the formation and prevention of the principal forms of scale, the losses due to scale, and the frequency of tube cleaning. The problem of cleaning curved tubes and the function of the various types of motors and heads are covered and illustrated in detail.

Traveling Grate Stoker

Over ten million square feet of boiler heating surface has been equipped with Coxe stokers for burning small sizes of anthracite, coke breeze and lignite, according to a sixteen-page catalog just issued by Combustion Engineering Company.

Recent improvements in details in this well-known stoker and its drive are described and all its parts are exceptionally well illustrated. A two-page blueprint spread shows typical settings of this stoker as applied to different types of boilers and numerous installation photographs are included. Air control, drive and furnace arrangement are discussed at some length.

John Morrell & Co. Adds Large Steam Generating Unit to Its Ottumwa Plant

By PAUL R. WALTER,
Engineer
Combustion Engineering Company, Inc.

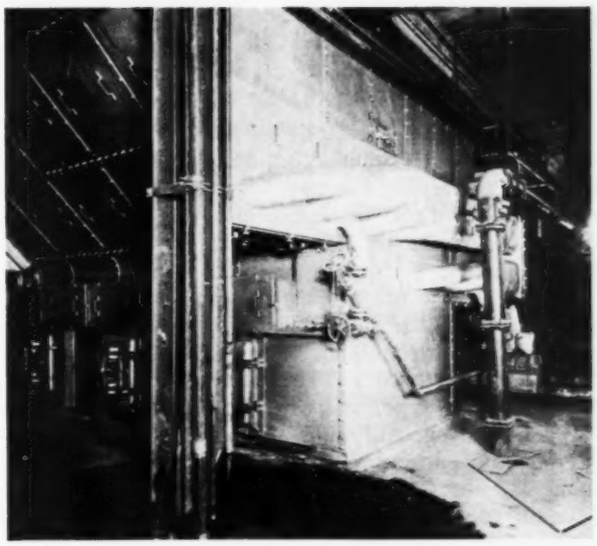
This new pulverized-coal-fired unit of 170,000 lb per hr output, which replaces four old units, has capacity sufficient to carry the total steam load of the plant 75 per cent of the time. It consists of a four-drum bent-tube boiler of the multiple circulation type, designed for 448-lb pressure, a plate-type air heater, and fin-tube furnace of the dry-bottom type. Iowa coal of 15 per cent moisture is burned with a maximum heat liberation of 20,800 Btu per cu ft and the gases after leaving the air heater pass through a "multicyclone" fly-ash eliminator to a 200-ft stack.

JOHN Morrell & Company is one of the largest packing concerns in the United States and one of the leading organizations specializing in the packing and curing of branded pork products. It owns and operates modern packing plants in the approximate center of the corn belt, the principal one of which has been located at Ottumwa, Iowa since 1878.

The steam generating facilities at this plant have recently been revamped under the direction of the company's consulting engineers, Ralph D. Thomas & Associates of Minneapolis and Mr. B. Winger, General Master Mechanic of the company, and include a large boiler unit which has just been placed in operation.

Previous to the present modernization program the plant had contained four 500-hp Stirling boilers fired with chain-grate stokers and one larger unit fired with pulverized coal. The stoker-fired boilers were about twenty years old, the superheaters had been burned out and had been removed, maintenance was becoming high on both the furnace settings and the stokers, and when the pulverized-coal-fired boiler was off the line it was difficult to handle growing steam demands with the old stoker-fired boilers. The new steam generating unit is large enough to carry the total steam load for about 75 per cent of the year and has ample capacity to carry all the power requirements of the plant on a by-product cycle.

The pressure and temperature were determined as a result of a survey and heat balance of the steam and electrical requirements. It was found that 425-lb pressure and 710 F steam temperature would make it possible to generate practically all of the power requirements as a by-product of the steam demands.



Front right-hand view below firing floor showing lower casings, front water-wall header box, side wall downtake tubes and blowoff piping and valves for enclosed side wall headers

Inasmuch as the first pulverized-coal-fired boiler had given satisfactory service with Iowa coal it was decided to adopt this method of firing for the new unit. Furthermore, the management felt that the installation of a different type of firing equipment might complicate matters with the operating personnel.

Steam is used at boiler pressure for engine-driven ammonia compressors, turbine-driven pumps, elevators, etc. It is also passed through reducing valves for process work and a large amount of steam is used at 5 lb for feedwater heating as well as process. The engines on the compressors exhaust against a 5-lb back pressure to meet the demands for steam at this pressure. At times there is not enough demand for low-pressure steam to permit the operation of the engine-driven compressors and one or more of them are operated on a condensing basis. With several engine-driven compressors in the plant it is very easy to switch from back-pressure operation to condensing operation.

The new steam generating unit is located in the space formerly occupied by a battery of the old Stirling boilers and consists of a 1000-hp C-E 4-drum, bent-tube boiler

of the multiple-circulation type equipped with an Elesco superheater, fin-tube, water-cooled furnace, and is fired with pulverized Iowa coal through two Riley flare-type burners supplied by Atrita mills. Preheated air for combustion and for drying the coal in the mills is supplied by a C-E plate-type air heater.

The unit is designed for a steam pressure of 448 lb per sq in. and the ultimate operating pressure at the superheater outlet will be 425 lb per sq in. It has a capacity operating range of from 150,000 to 170,000 lb of steam per hour actual evaporation from feedwater at 212 F. Final steam temperatures for these capacities range from 580 to 710 F and an efficiency of 84.8 per cent was guaranteed at 75,000 lb per hr evaporation.

For the present, the steam pressure at the superheater outlet will be 190 lb per sq in. to correspond with that of the other boilers in operation at the plant, the capacity range at this pressure being the same as mentioned above. Final steam temperatures for present operation range from 460 F to 560 F and an efficiency of 85.4 per cent are guaranteed at 75,000 lb per hr evaporation at the lower pressure.

Welded Drums of High Tensile Steel

The drums of the new unit are fusion welded and constructed of steel having an ultimate tensile strength of 70,000 lb per sq in., the upper front and middle drums being $^{15}/_{16}$-in. plate thickness, and the rear and mud drums $1^1/_2$ in. thick. The tubes are arranged in three banks, making a total of 17 tubes deep and 36 rows in width. The tubes are baffled into three gas passes with a combination of monolithic cross baffles used in conjunction with shiplap tiles for the semi-vertical portions of the baffles. The superheater, which is of the convection type, is located in the interbank space between the front and middle banks of boiler tubes. It has a heating surface of 1980 sq ft and is made of $1^3/_4$-in. diameter elements.

Steam connection between the boiler drum and the saturated head of the superheater is effected by a series of $3^1/_4$-in. diameter tubes located just above and parallel to the boiler circulating tubes. This type of construction permits the connecting tubes to be contained beneath the boiler roof and its casing, and eliminates the necessity of an external connecting pipe.

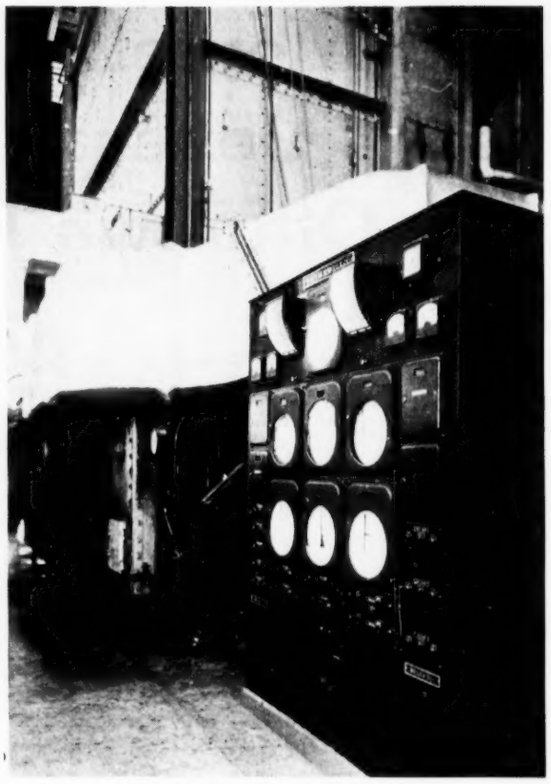
The fuel by which this unit is fired is an Iowa coal having the following proximate analysis:

	As Fired	Dry
Moisture	15	
Volatile matter	35	41.20
Fixed carbon	35	41.20
Ash	15	17.60
Sulphur	6	7.07
Btu per lb	9600	11,300
Fusion Temperature	1850	

This is classed by the U. S. Bureau of Mines as a low-grade non-coking bituminous rank coal.

In view of the fuel that is being burned and a six-day load factor of 85 to 90 per cent at which the unit is to be operated, special consideration was given to the furnace and air heater arrangement as well as the provision for supplying high temperature air for mill drying.

The furnace is constructed entirely of C-E $3^1/_4$-in. No. 6 BWG finned tubes backed up by $2^1/_2$-in. molded tile, 3 in. of rockwool and No. 10 BWG casing, with exception of the burner wall which is a Detrick suspended wall, the inside face of which is shaded by a plain screen



Boiler control board containing Hays pointer draft gages, Cochrane pressure gages and meters and Carrick combustion control

of $3^1/_4$-in. No. 8 BWG tubes that bend around the burner openings and the boiler side walls which are also Detrick suspended walls. Both the burner wall and the boiler sidewalls are insulated with a $2^1/_2$-in. thickness of plastic insulation and are covered by No. 10 BWG casings. The total water-wall heating surface amounts to 2645 sq ft.

One of the novel features of the furnace construction is the inclusion within the casings of all of the water-wall downtake and riser tubes above the firing floor. This is arranged by having a rear furnace wall construction in which the fin tubes are backed by a 2-in. thickness of monolithic refractory, supported from a No. 14 BWG casing placed just forward of the water-wall downtake tubes from the mud drum. To the rear of the downtakes a 3-in. thickness of rockwool is held in place by a No. 10 BWG steel plate casing which also supports the inner No. 14 gage casing.

The riser tubes from the forward half of the side water wall leave the upper headers horizontally and after making vertical S bends fan out horizontally and pass over the superheater headers to connect to the middle boiler drum. These tubes are enclosed within a double-paneled insulated casing. The front and rear water walls discharge directly into the boiler drums and therefore require no riser tubes. A slag screen extends across the lower part of the furnace.

All of the water-wall headers are $7^1/_4$ in. square, $^3/_4$ in. thick and, with the exception of the side-wall junction headers previously mentioned, are enclosed by double-paneled insulated casings having removable panels for access to the headers.

The furnace has a volume of approximately 8200 cu

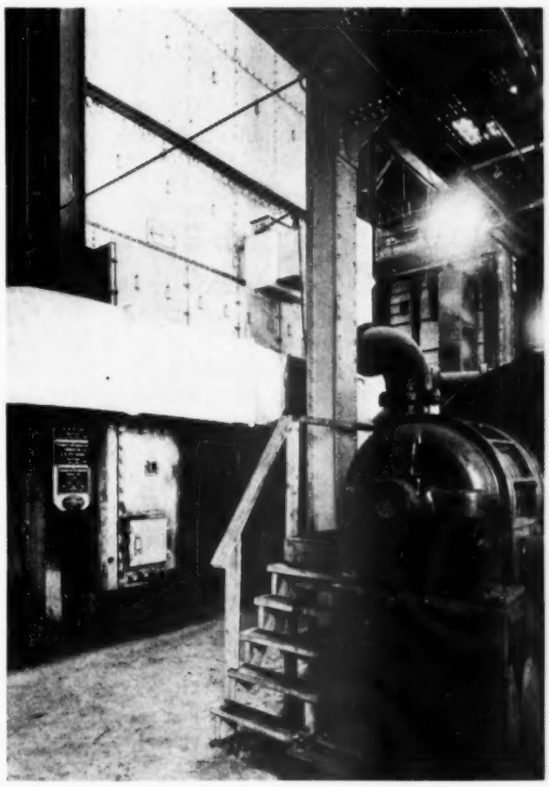
ft and at the peak load has a heat liberation of 20,800 Btu per cu ft per hr.

The air heater is a C-E plate-type consisting of fifty elements 5 ft wide by 22 ft long arranged in two groups to form a split-type construction and has a heating surface of 11,000 sq ft. It is located directly to the rear of the boiler so its front casing forms the rear wall of the boiler. Thus the gases leaving the boiler pass down through the heater to outlet connections which are located below the firing room floor.

Air from two Buffalo Forge fans, placed in the basement, is forced into a plenum chamber located between the two groups of air heater elements. From this chamber it passes up through the heater, discharging on both sides of it into secondary air ducts which are brought around to the front of the unit and connected to the burner windboxes.

Air temperatures for present operation range from 390 to 460 F while gases leaving the heater range from 280 to 335 F. For the future operating conditions air temperatures will range from 440 to 490 F with gases leaving at from 320 to 370 F.

After leaving the air heater the gases enter a duct which passes out of the boiler room building and connects to a Prat Daniel "Multi-Cyclone" fly-ash eliminator installed on the suction side of the induced-draft fan. The fan discharges into a 200-ft stack which is 10 ft in diameter. Provision has been made so that in the future if desired the air preheater and the fly-ash eliminator can be by-passed at low loads by having a duct connection from the boiler outlet direct to the stack. Ash and soot disposal is handled by means of a Nuveyor ash conveyor system.



Front view of unit taken at firing floor showing front casing, upper front water-wall header box, hot air duct to burners and hot gas duct connection to furnace

In view of the moisture content of the fuel being burned, which at times will run as high as 20 per cent, special provision has been made for supplying high temperature air to the mill for the drying of the coal. Air for this purpose can be supplied from two sources. The first is by means of air taken from the secondary air ducts through a regulating louvre damper to a system of primary air ductwork which passes vertically downward between the two burners to below the firing floor whence it is carried over to just below the two mills where connections again pass up through the floor to the primary air intake connections on the mills.

Furnace Gases for Mill Drying

Inasmuch as it was believed that temperatures even higher than this would be required, an arrangement has been provided whereby air tempered furnace gases can be used for this purpose. The arrangement provided is constructed as follows:

A rectangular-sectioned cast-iron refractory-lined chamber supported by the front casing is placed against the front water-wall tubes from which the fins have been omitted for the height and width of the chamber. Around the outside end of the chamber is placed a steel duct having a cross-section large enough to permit an approximate clearance of 3 in. all around the outside of the chamber. Around both the chamber and the duct a steel plate box is fastened which has its top formed of a channel frame containing a louvre damper. The duct is connected to a louvre damper located on top of the first mentioned primary air duct work.

When hot gases are used for mill drying the damper between the secondary and primary ducts is closed and the one on top of the primary air duct is opened as required. Suction from the mills draws hot gas from the furnace and room air through the upper part of the above-mentioned box. The louvre damper on top of the box regulates the amount of room air admitted and thereby the amount of furnace gas and the temperature of the mixture. Since the hot gas is admitted to the center of the duct and the room air is admitted as a film around it until complete mixture occurs, there is no contact between the high temperature gas and the ductwork.

In 1930 the John Morrell Company installed in this plant a unit somewhat similar to the new unit, as was mentioned at the beginning of this description, but the earlier unit had less water-wall surface and was without an air preheater. That unit performed so satisfactorily that when it became evident that additional steam generating equipment was required a unit having even a higher efficiency, with a maximum of water-wall surface and an air preheater was specified.

The installation of the new unit serves to illustrate that high efficiency units for industrial plants with high load factors have proved themselves to be a better investment than plain boiler installations without water-walls and heat recovery equipment and are, therefore, rapidly replacing them.

J. C. Parker, has resigned as president of the Brooklyn Edison Company to become vice-president of the Consolidated Gas Company, New York. **Frank W. Smith,** has been elected President of the Brooklyn Edison Company in addition to his duties as President of the Consolidated Gas Company.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Pulverized Coal Firing in Australia

An article by H. Escher in the November issue of *The Commonwealth Engineer* (Australia) reviews the status of pulverized coal firing in Australia. Although at present pulverized coal firing accounts for only 8 per cent of the water-tube boiler capacity in that country, installations now under construction will shortly increase this to approximately 12 per cent. In fact a large proportion of the new boiler installations will employ this method of firing.

The crushing of some of the soft coals in the southern fields of New South Wales produces large quantities of fines and it has been found advantageous to divide the fines into two products, one being screenings between $^1/_2$ and $^1/_8$ in. which is used on stokers and those under $^1/_8$ in. being employed in pulverizing mills. The grindability of these coals compares favorably with that of the softest American coals. Coals from the western fields of New South Wales are much harder. The calorific values of the coals now being burned in pulverized form range from 10,200 to 13,200 Btu per lb; the volatile from 18.9 to 34.5 and the moisture from 0.35 to 10.9 per cent, the softest of these coals being very low in moisture and having a high fusing temperature of the ash.

Direct Drive from Turbine

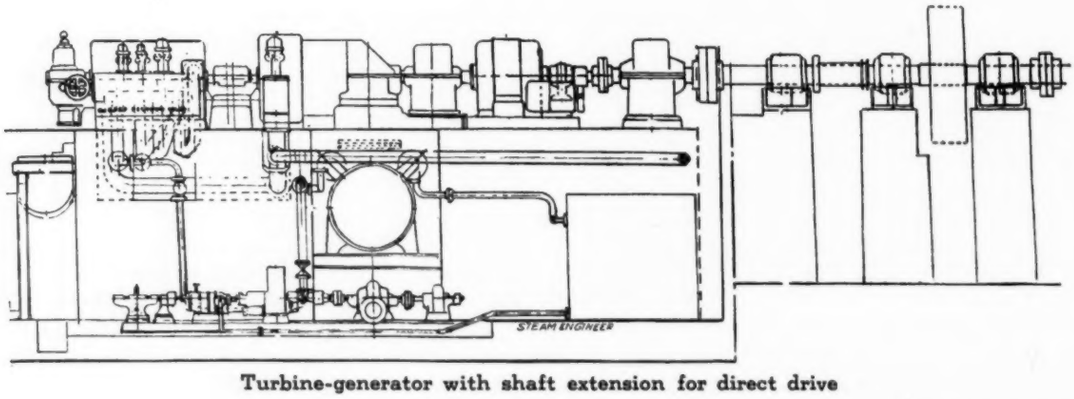
A preference for direct mill drive from steam turbines apparently persists in some industrial plants in England, as is shown by a description of the new power plant of A & A Crompton & Co. near Oldham appearing in the January issue of *The Steam Engineer*. Two separate but adjacent textile mills are supplied by the central plant in which is installed a 2500-kw turbine. The arrangement provides for electric supply to the farther mill but the mill at which the plant is located is supplied by direct drive from the turbine. This unit has an extended shaft and between the turbine and the generator there is interposed a Stal reduction gear to reduce the speed from 3600 to 1000 rpm. On the far side of the generator a chain drive connects to a 9-kw exciter while the main shaft couples up with a second reduction gear which reduces the speed of the shafting to 228 rpm. At this speed the shafting passes through the wall of the turbine room to drive the main shaft of the mill. This shafting is fitted with a Siemens torsion meter which records the power supplied to this section of the works. The accompanying sketch shows the layout of the turbine for this direct drive.

Secondary Combustion Caused Stack Failure

An interesting case of failure of a brick stack due to excessive fuel consumption is recorded in the January issue of *Engineering and Boiler House Review* (London). The stack, which was 8 ft diameter and 60 ft high, served a Lancashire boiler and had been in use about four years. Increased steam demands necessitated forcing the boiler to the extent of nearly doubling the fuel burned per hour and considerable secondary combustion was observed to be taking place in the flues. Cracks consequently developed near the base of the stack and flames occasionally extended from them. The condition rapidly grew worse until it seriously affected the stability of the stack.

Small Plant Shows High Efficiency

To counteract a prevailing opinion that high efficiencies are attainable only in large power stations with highly-trained operating personnel, T. B. Morley in *Engineering* of January 10, 1936 cites the performance of the small power plant supplying heat and electricity for the Manchester College of Technology. This plant, in-



Turbine-generator with shaft extension for direct drive

stalled in 1934, has a Super-Lancashire type of boiler rated at 10,000 lb of steam per hour and operating at 170-lb steam pressure and 500 F. It is fired by a sprinkler-type stoker and has an air preheater and forced-draft. With nut coal of 8 per cent ash, 3.91 per cent moisture, 36 per cent volatile and 13,430 Btu per lb net heating value, a net overall efficiency of 89.34 per cent was attained on an 8-hr test.

Largest Turbine-Generator in Europe

At the Battersea Station of the London Power Company there went into service last September a 105,000-kw Metropolitan-Vickers turbine-generator which is said to be the largest in Europe. This unit is described in detail in the January 17 issue of *Engineering*. The turbine is of the three-cylinder design operating with an initial steam pressure of from 570 to 600 lb per sq in. and a temperature of 800 to 850 F. Its speed is 1500 rpm. The main generator is rated at 100,000 kw and the shaft carries a 5000-kw service generator, also a direct coupled exciter. The most economical rating of the unit is 84,000 kw.

The high-pressure cylinder is of molybdenum steel and the moving blades in this section are of rolled-section stainless steel with separate packing pieces. The cylinder is arranged to give one velocity compounded stage followed by sixteen single-impulse stages. For loads up to 63,000 kw steam is admitted before the velocity stage; for loads up to 84,000 kw it is admitted after the velocity stage; while for loads up to the maximum continuous rating of 105,000 kw admission is after the eighth impulse stage.

The intermediate-pressure cylinder has eighteen impulse stages. The moving blades of the first fourteen of these stages are of stainless steel while those of the last four are of nickel steel.

The low-pressure cylinder is of the double-flow type with twin exhausts to separate condensers, each section consisting of seven impulse stages and a duplex multi-exhaust. The casing is of cast iron and the moving blades of nickel steel.

Output of German Boiler Manufacturers

Zeitschrift des Vereines deutscher Ingenieure for October 26, 1935 contains a digest of a survey of orders placed in Germany for various types of boilers for the ten-year period 1924 to 1934. The total output of the boiler manufacturers in 1924, for all types of boilers amounted to 1,323,500 sq ft, and in 1934 it was 1,796,900. The low point of production was in 1932 when only 269,000 sq ft was put out. About half the boilers built in 1934 were of the inclined water-tube type. The majority of these boilers are designed to operate at moderate pressures from 250 to 450 lb. The very small number of high-pressure units is marked. It is significant that traveling grates are employed with over half the boiler heating surface installed during this period.

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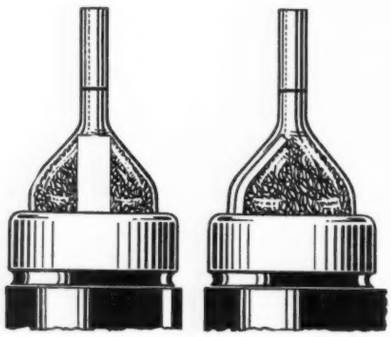
NEW EQUIPMENT

of interest to steam plant engineers

Vision Panel for Orsat

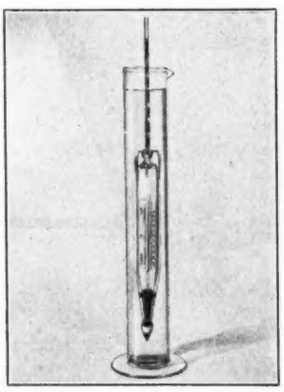
To improve the visibility of the solutions in the absorption chambers of the Orsat type of gas analyzers, using fibrous material for surface absorption, a vision panel has been developed by the Ellison Draft Gage Company, Chicago. It is



made of opal glass and is placed in the front of the chambers with a space between the panel and the chamber wall for solution passage. With the white background, close to the wall of the chamber, the solutions are easily visible even at a distance of several feet.

Automatic Compensating Hydrometer

The Permutit Company, New York, has lately brought out a new automatic compensating hydrometer, under the trade name "Pacometer," for the measurement and control of salt concentrations in boiler water. This instrument is calibrated for quick reading at either high or low temperature ranges and has a self-contained thermometric correction scale in the bulk which scale shows directly the density correction in the same concentration units as the stem itself. The stem is made of tough non-corrodible polished



metal with the scale reading into the surface. Because of the small cross-sectional areas of the metal stem (a glass stem, of this cross-section would be too fragile) a very small change in density causes a relatively large rise or fall of the stem, thus insuring high sensitivity. Accuracy of readings within 10 grains per gallon are guaranteed.

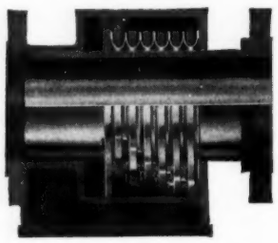
The metal stem is attached to the glass bulb by two sets of spring prongs that permit it to be detached for cleaning.

Packless Expansion Joint

The American District Steam Company, North Tonawanda, N. Y., has brought out a packless expansion joint, based on an entirely new principle for controlling pipe expansion in steam and hot water lines, or pipe lines conveying gases or fluids subject to temperature variations.

The expansion element is a series of die-formed "U-rings" of stainless steel, welded together without transverse seams. One end is welded to the wrought steel body of the joint and the opposite end is welded to a plate that is, in turn, welded to the sleeve.

The joint is installed with the expansion element compressed so that under actual operating conditions, the element is in a neutral or normal position, free

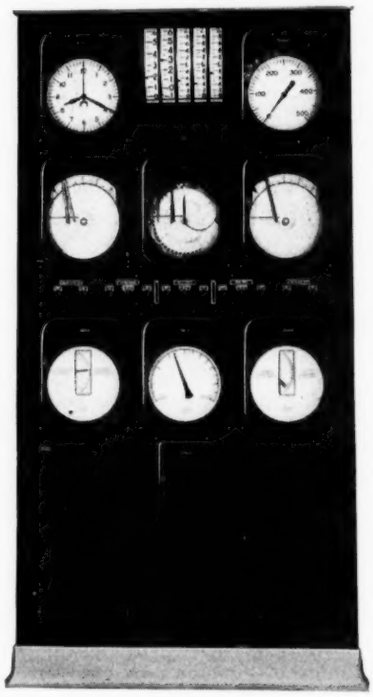


from flexing strain when under maximum line pressure. Control rings and stop-bolts distribute the expansion and contraction movement equally through the U-rings.

The new joint is guided at three points to permit the sleeve to move freely without binding. It is available for pressures up to 400 lb and temperatures to 800 F with flanged ends or beveled ends for welding directly into the pipe line; with or without anchor base.

Combustion Control Panel

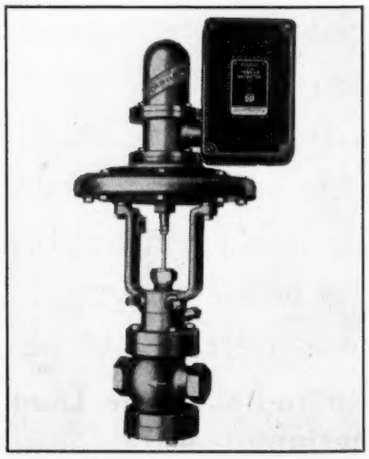
A complete instrument and control panel for boiler operation has recently been announced by The Hays Corporation, Michigan City, Inc. It includes the necessary indicating, recording and integrating meters and combustion control equipment with provision for selecting automatic operation or manual control of the whole system or any part. The new control uses electricity without open contacts or relays giving distinct advantages in transmission and sensitivity. Air, water, oil or electricity may be used as the operating medium for power units affording flexibility and adaptability. Adjustments of relationships of boiler loadings, air-fuel ratio and pressure or draft settings can be conveniently made at any time on the panel. The panel shown is



typical but any combination of instruments and controls may be assembled to meet individual plant requirements and the control calibrated to the boiler and fuel burning equipment being used. The usual assembly is: Indicating, pressure and draft gages; indicating, recording and integrating steam and water meters; and indicating and recording CO_2, draft, pressure, temperature and boiler water level.

Vernier Valvactor

A new accessory for air-operated control valves, the "Vernier Valvactor," has been developed by the Foxboro Company to eliminate valve sticking and to assure hair-line valve positioning. This device enables throttling type air-operated control instruments to make small gradual adjustments of the control valve position regardless of friction or hysteresis. It is claimed that the air from the control in-



strument need change as little as $^1/_8$ in. of water to cause a corrective positioning of the valve and force the stem to take a position within $^1/_{1000}$ in. of the previous one.

The Vernier Valvactor guarantees exact valve response where the valve stem packing must be very tight to prevent leakage; where the fluids are viscous or contain solids; where friction is otherwise unavoidable or wherever there is danger of valve friction developing.

The unit is mounted in a cast aluminum case, is completely weatherproof, and may be exposed to the elements. The case is also available in gas-tight construction properly vented so that it may also be operated indoors on gas supply with the vent piped to a safe spilling point.

The Vernier Valvactor can be attached directly to the spring housing of all sizes of Stabilflo valves. For needle valves and valves without the Stabilflo type of motor, the Vernier Valvactor is mounted on the side of the motor supports. It can be installed very easily to valves in the field, with but little interruption to service.

The Foxboro Company, Foxboro, Mass., will gladly send additional information to any interested person.

Forged Steel Valves

A line of improved forged-steel globe valves has been announced by the Hancock Valve Division of Consolidated Ashcroft Hancock Company, Inc., Bridgeport, Connecticut. These valves are made for pressure ratings up to 1500 lb per sq in. and are specially designed with a tongue-and-groove bolted bonnet for high-temperature service. They are made in either cone or plug type and the valve seat ring and disk are made of heat-treated stainless steel. The makers claim that this trim material is exceptionally hard, and therefore resists wire drawing, indenting and galling and reduces repairs. Other features are a long condensation chamber to protect and increase the life of the packing; all wearing parts renewable; and a seat ring that is easily removed with a standard hex wrench. The makers further state that these valves are easy to repack in service because of a special stainless steel back seat, and because the gland bolts come completely out allowing ample finger room and because of a relief plug for bleeding condensation chamber while repacking.

Gasket with Centering Guide

Flexitallic Gasket Company, Camden, N. J., has brought out a new, "Style D," gasket for raised face, plain, Van Stone or

Cranelap pipe flanges for pressures up to 1500 lb. Embodying the usual features of Flexitallic construction, the new gasket has the added feature of a centering guide to insure correct seating and simplify installation. This centering guide is so designed that the gasket proper is entirely within the bearing faces and is made in conformity with the A.S.M.E. Standards as to diameter of bolt circle, number and size of bolts. The guides fit diametrically opposite bolts.

For pressures up to 600 lb per sq in. cold-rolled steel is employed, above this pressure, and for temperatures over 500 F, stainless steel or monel metal is employed. For special fluid conditions copper or bronze may be used.

Detector to Locate Hidden Pipes

A new magnetic detector of extreme sensitivity has been developed by the General Electric Company, making easier and more efficient the search for distant or deeply-laid pipes.

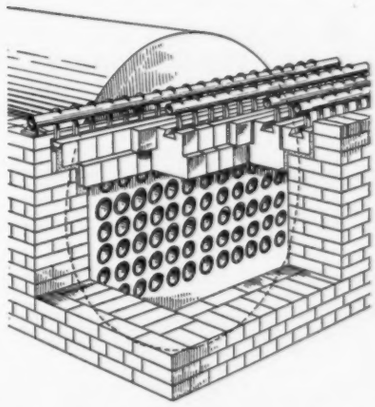
Previous equipment for this purpose has made use of the ordinary compass and dip needle, and was neither convenient nor precise in its operation, it being limited to depths of 15 to 18 inches.

The new detector is a surveying compass with an adjustable bar magnet for reducing the control effects of the earth's magnetic field, thereby rendering the needle more susceptible to magnetic disturbances produced by a "missing" pipe. The bar magnet is adjustable for height and azimuth. Affixed to the compass box and turning with it are two radial fins of high permeability, low hysteresis magnetic material, serving as magnetic antennae. These fins effect a substantial increase in sensitivity, and are mounted on a crossbar.

The detector is sensitive to iron or steel pipe lines having any magnetic bearing, and at a considerable distance away. It may be used with or without electric current through the pipe, although the establishment of a small current makes for easier and more certain search. Non-magnetic pipes obviously require an electric current in conducting a search.

Rear Arch for H.R.T. Boilers

Geo. P. Reintjes Company, furnace arch and wall manufacturers of Kansas City, Missouri, have adapted their standard wall tiles for use as rear arches on horizontal return-tubular boilers. The design is such that each tile is individually hung by an independent casting from a



pipe. Infiltration of excess air is prevented by the placing of a standard 9-in. fire brick between each pair of tiles, yet provision is made for freedom of expansion and contraction. The advantage claimed the flat suspended arch is that it provides turbulence in the gases so that all of the boiler tubes receive an equal proportion of the hot gases, thereby increasing boiler efficiency.

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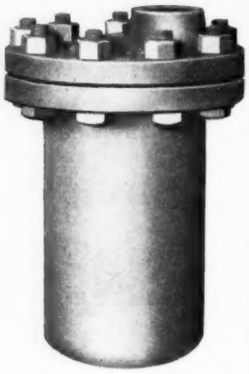

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EQUIPMENT SALES

Boiler, Stoker, Pulverized Fuel

as reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

Boiler Sales

Orders for 92 water-tube and h.r.t. boilers were placed in December

	Number	Square Feet
December, 1935	92	319,765
December, 1934	50	128,903
January to December (inclusive, 1935)	1,021	3,378,966
Same period, 1934	852	2,436,550

NEW ORDERS, BY KIND, PLACED IN DECEMBER 1934–1935

Kind	December 1935		December 1934	
	Number	Square Feet	Number	Square Feet
Stationary:				
Water tube	57	265,701	28	108,829
Horizontal return tubular	35	54,064	22	20,074
	92	319,765	50	128,903

Mechanical Stoker Sales

Orders for 196 stokers Class 4* totaling 34,166 hp were reported in December by 68 manufacturers

	Installed under			
	Fire-tube Boilers		Water-tube Boilers	
	No.	Horsepower	No.	Horsepower
December 1935	159	18,379	37	15,787
December 1934	137	17,394	30	10,805
January to December (inclusive, 1935)	1,754	225,927	556	209,027
Same period, 1934	1,654	206,640	476	193,505

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 33 pulverizers with a total capacity of 226,835 lb per hr were placed in December

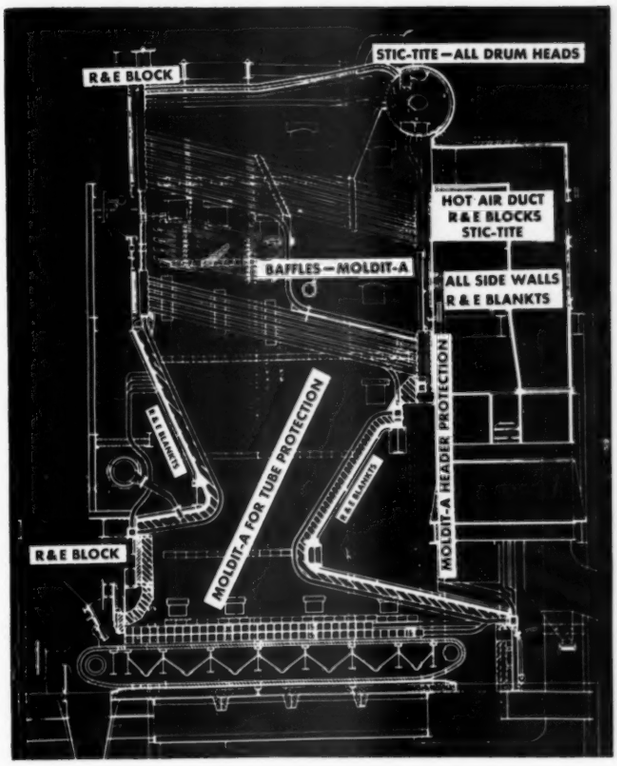
STORAGE SYSTEM

	Pulverizers				Water-tube Boilers		
	Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
December 1935	..	..	..	.....	..	.....	.....
December 1934	..	..	..	.....	..	.....	.....
January to December (inclusive, 1935)	..	..	..	.....	..	.....	.....
Same period, 1934	2	1	1	46,000	*	*	*

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
December 1935	33	28	5	226,835	23	155,152	2,190,920
December 1934	8	7	1	25,030	6	42,778	360,000
January to December (inclusive, 1935)	156	114	42	1,025,275	121	863,739	8,994,480
Same period, 1934	90	64	26	527,815	71	454,795	4,532,370
					Fire-tube Boilers		
December 1935	..	..	..	....	..	....	....
December 1934	..	..	..	....	..	....	....
January to December (inclusive, 1935)	7	1	6	6,685	7	12,830	68,750
Same period, 1934	12	3	9	11,765	13	15,486	111,900

* Data not available.



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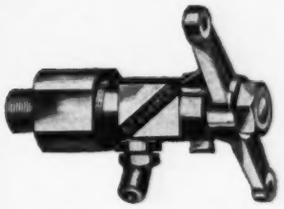
LEAKLESS GAGE COCKS



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WATER GAGE HEADQUARTERS

Midwest Power Engineering Conference and Exposition Plans

Features of paramount interest to the power industry are being incorporated in the programs of the Midwest Power Engineering Conference and the Midwest Engineering and Power Exposition to be held in Chicago, April 20 to 24, according to a joint announcement by Frank D. Chase, President of the Conference and George E. Pfisterer, Manager of the Exposition.

The Conference sessions will be held in the Palmer House in the mornings and at the International Amphitheatre in the afternoon. The Exposition will be held at the Amphitheatre. Among the Conference sessions already organized are those on power economics, coal, refrigeration and power transmission. One of the papers at the power economics session will be on "Trends in Power Research" by C. F. Hirshfeld of the Detroit Edison Company. The coal session will include such topics as "Use Value," "Equipment," "Simplification," "Fuel Economy" and "Coordination of Controls." Joseph Harrington, Chicago engineer, will present a paper on "Simplification of Coal Sizing."

Insulation and refrigerants will be among the topics at the session on refrigeration. L. S. Morse, President of the American Society of Refrigeration Engineers, will discuss "Power Used in Air Conditioning."

The fourth session now organized will deal with transmission of power to machinery by means of belts and direct motor drives.

Diesel, internal combustion power, fuel power and fuel burning equipment will also be featured.

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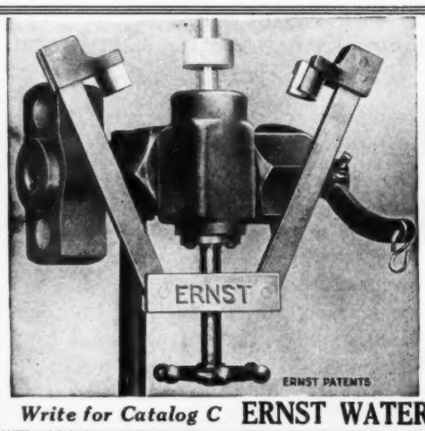

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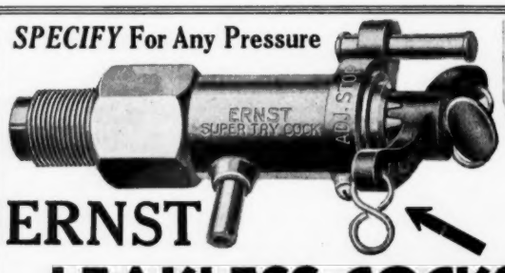

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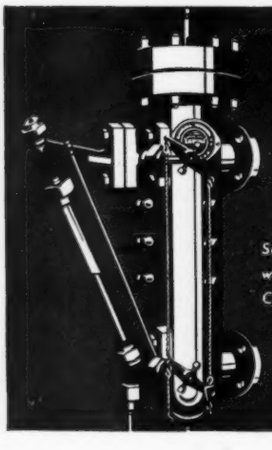

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